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CHARLES B. DAVENPORT
BRADLEY M. DAVIS
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THE INHERITANCE OF STREPTOMYCIN RESISTANCE AND DEPENDENCE IN CROSSES OF ESCHERICHIA COLI

H. B. NEWCOMBE AND M. H. NYHOLM
National Research Council of Canada, Atomic Energy Project, Chalk River, Ontario

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ESCHERICHIA COLI mutates by a single step to a high level of streptomycin resistance, and in strain B/r these mutations occur spontaneously with an average frequency of about 1 per 5×10^9 cell divisions (NEWCOMBE and HAWIRKO 1949; SCOTT 1949). Using ultraviolet or gamma irradiation similar changes can be produced in much larger numbers (NEWCOMBE 1949).

Two main categories of mutant have been described: streptomycin resistant (*sr*) and streptomycin dependent (*sd*), the former having the ability to grow either in the presence or in the absence of the drug, the latter growing only in its presence. Within the *sd* category is a range of forms differing with respect to the drug concentration required. The two extremes of this range are represented by mutants requiring as little as one or two units per ml on the one hand and as much as 500 units per ml on the other.

The *sd* mutants are capable of further mutational changes resulting in the restoration of drug independence. Such two-step mutants may be streptomycin sensitive (*sd/ss*), streptomycin resistant (*sd/sr*), or intermediate between the two (NEWCOMBE 1949, NEWCOMBE and NYHOLM 1950).

The bacterial crosses described here were made to determine whether or not there is an allelic series of genes corresponding to the various streptomycin mutants. In addition to this, information concerning the linkage relationships of streptomycin resistance and certain genetic marker characters has been sought.

MATERIALS

Four bacterial lines derived from *E. coli* strain K12 were very kindly supplied by DR. JOSHUA LEDERBERG. These had the following mutant characters:

line Y-40,	M^-, B^-, V_1^r;
line Y-53,	B_1^-, T^-, L^-, Lac^-;
line 58–161,	M^-, B^-;
line W-677,	B_1^-, T^-, L^-, Lac^-, Mal^-, Gal^-, Ara^-, Xyl^-, Mtl^-, V_1^r.

(M^-, B^-, T^-, L^-, and B_1^- indicate a requirement for methionine, biotin, threonine, leucine, and thiamin respectively; Lac^-, Mal^-, Gal^-, Ara^-, Xyl^-, and Mtl^- indicate an inability to ferment lactose, maltose, D-galactose, L-arabinose, D-xylose, and D-mannitol respectively; and V_1^r indicates resistance to phages T1 and T5. The wild type characters are designated + where the mutants are −, and s where the mutant is r. Of the above character differences all except *Mtl* were used in the present studies).

Crosses have been made with these streptomycin sensitive (*ss*) lines, and

with the streptomycin mutants (*sr*, *sd*, *sd/ss*, and *sd/sr*) derived from them in this laboratory.

METHODS

Sr and *sd* mutants were obtained from ultraviolet (2537 Å) irradiated bacterial suspensions using the following procedure: Samples from the suspension were poured with 2 ml of melted soft agar (0.7 percent agar in Difco nutrient broth) over the surface of Difco Nutrient Agar plates, and when solid a second 2 ml layer of agar was added to prevent the developing microcolonies from being disturbed by subsequent treatment. After a preliminary incubation of 3 to 4 hours at 37°C, streptomycin was applied in the form of a third agar layer containing 10,000 units of the drug. The plates were chilled overnight to permit diffusion and were then incubated until colonies appeared.

Sd/ss and *sd/sr* two-step mutants were obtained simply by spreading irradiated suspensions of the *sd* form on the surface of nutrient agar in the absence of streptomycin, and incubating at 37° until colonies developed. Cultures from these colonies were categorized by streaking in duplicate on nutrient agar in the absence and in the presence of streptomycin (1000 units per ml). When growth took place only in the absence of the drug the culture was termed *sd/ss*; when it occurred on both plates the culture was termed *sd/sr*. This classification is arbitrary since the mutants exhibit a more or less continuous range with regard to degree of resistance. The particular *sd/ss* and *sd/sr* forms chosen for crossing were from among the most sensitive and the most resistant.

Crosses between parent strains, requiring respectively biotin and methionine, and threonine, leucine and thiamin, were made by spreading washed suspensions (containing 10^8 to 10^9 cells of each of the two types) on a growth factor deficient medium. This consisted of mineral salts, glucose, and asparagine (the "minimal agar" of TATUM and LEDERBERG 1947), and except where otherwise stated was supplemented with thiamin. On such a medium the parent forms are restricted in their growth while certain sexually derived recombinants multiply to produce colonies. When the five factors are absent, all recombinants that form colonies are growth factor independent. In this respect they resemble the original strain from which the parent forms were derived and are therefore termed "prototrophs" (LEDERBERG and TATUM 1946). When thiamin is added the number of colonies is increased and, since many of them require thiamin and are therefore not true prototrophs, they are known by the more general name of "growth factor recombinants."

Colonies appeared after two to three days incubation, and were categorized for streptomycin response and lactose fermentation (a useful marker character) by growing in a liquid minimal medium plus thiamin, diluting (1/100), and streaking on Levine's eosin methylene blue-lactose agar (known as EMB-lactose). In the latter medium sugar fermentation is indicated by a deep blue coloration of the streak. Duplicate plates were used, one of which had been cross-streaked previously with streptomycin (one loopful of a

solution containing 10,000 units per ml) as described by DEMEREC and FANO (1945) for bacteriophage. In certain experiments additional tests were made in a similar manner for fermentation of other sugars (substituting these for the lactose in the EMB medium) and for phage T1 resistance.

When strains from which *sd* segregants might arise are to be crossed, streptomycin must be present so that these can be recovered. Provided that both parents are capable of growth in the presence of the drug, this can be incorporated in the medium in a concentration of 1000 units per ml. However, where one of the parents is sensitive, crossing must be allowed to take place in the absence of streptomycin (16 to 18 hours at 37°C is sufficient), the drug then being applied as a spray (in these experiments approximately 0.2 to 0.3 ml of a solution containing 100,000 units per ml was used for each plate). In order that no *ss* or *sd* segregants should be missed, all of the crosses involving an *sd* parent (or a parent derived by further mutation from the *sd* form) were made both with and without streptomycin.

A peculiarity in the streptomycin response of the *sd* mutants should be noted. When these were cross-streaked with streptomycin on nutrient agar, growth was, as would be expected, normal in the presence of the drug and thin or invisible where the drug was absent. However, in similar tests on minimal agar supplemented with the five factors, growth was not stimulated by streptomycin and was equally thin in its presence and in its absence. Thus the *sd* parent forms seemed to have requirements in addition to the stated ones.

The *sd* growth factor recombinants derived by crossing such parents did not exhibit this fastidiousness but showed a normal response to streptomycin on both the synthetic and the complete medium. This difference between *sd* parent and *sd* growth factor recombinants is assumed to be due to the segregation of a modifier gene (or genes).

TABLE 1

Segregation of streptomycin resistance, lactose fermentation, and phage T1 resistance, when streptomycin resistance is introduced in alternative parents.

	RECOMBINATION CLASSES			CROSS A (Y-40×Y-53/*sr*)		CROSS B (Y-40/*sr*×Y-53)	
	Str.	*Lac*$_1$	T1	COLONIES	%	COLONIES	%
1	r	+	r	86	34	7	3
2	r	+	s	11	4	1	0.4
3	r	−	r	84	33	8	3
4	r	−	s	51	20	3	1
5	s	+	r	11	4	73	30
6	s	+	s	0	0	4	2
7	s	−	r	8	3	88	36
8	s	−	s	5	2	59	24
Total colonies tested				256	—	244	—
% *sr*				—	91	—	8

sr CROSSES

The segregation of streptomycin resistance, lactose fermentation, and phage resistance is shown in table 1. Two crosses were made (using the lines Y-40 and Y-53) in which streptomycin resistance was introduced in alternative parents. Where a mutant character is studied in this manner the term "reversed crosses" will be used.

It will be noted that somewhat more than 90 percent of the descendent growth factor recombinants ($M^+ B^+ T^+ L^+$) resemble the Y-53 ($M^+ B^+ T^- L^-$ parent with regard to streptomycin response, a fact which would suggest linkage between *sr* and the *M B* loci. However, since the $M^- B^-$ descendents from the crosses cannot be examined there is no certainty of such linkage, and the situation is best described by saying that the *sr* locus from the $B^- M^-$ parent tends not to recombine with $B^+ M^+$. This statement leaves open the possibility of loss at some stage between the first steps of zygote formation and the development of the haploid descendents. That there is loss, and that it occurs early in this process is indicated by the behaviour of diploid heterozygotes from ($B^- M^-$) *ss*×($B^+ M^+$) *sr* crosses. A number of these have been examined by DOUDOROFF and LEDERBERG (personal communications, and LEDERBERG 1950) and in all cases they have given rise only to *sr* forms when permitted to segregate on a complete medium. This could be due to the gene for streptomycin resistance being present in the diploids either in the hemizygous or the homozygous state. Both of these states have in fact been demonstrated for other loci, certain lactose negative diploids being homozygous Lac^- and certain maltose negative diploids being hemizygous Mal^- (LEDERBERG, personal communication).

Table 2 shows no indication of linkage between streptomycin response and either lactose fermentation or phage T1 resistance. Similarly the streptomycin and thiamin loci appear to segregate independently (data not included in the table).

Linkage has been observed between *sr* and the sugar fermentations other

TABLE 2

Correlation between the inheritance of streptomycin resistance and ability to ferment galactose, arabinose, xylose, and maltose, in the cross: 58-161/sr×W-677.

SUGAR FERMENTATION	NUMBERS OF COLONIES OBSERVED		PERCENT		PROPORTION OF FERMENTERS IN *sr*/PROPORTION IN *ss* COLONIES
	ss	*sr*	*ss*	*sr*	
Gal^+	49	18	3	23	7
Ara^+	118	14	8	18	2
Xyl^+	25	14	2	18	11
Mal^+	22	19	1	25	18
Total colonies tested	1530	77			

Note: Lac^+ segregants constitute 34 percent of the *ss* colonies and 35 percent of the *sr* colonies. Lactose fermentation thus appears to be inherited independently of streptomycin resistance.

than lactose (i.e. galactose, arabinose, xylose, and maltose) using lines W-677 and 58-161 (see table 2). It is not however, such as to enable the loci for these characters to be placed in a linear order (data to be published separately). Similar observations concerning the anomalous inheritance of these particular sugar fermentations have already been made by LEDERBERG and by CAVALLI (personal communications) and the possible significance of this extraordinary phenomenon will not be considered here. It is of interest, however, that this anomalous inheritance is shared by the gene for streptomycin resistance.

To determine whether more than one locus may mutate to produce streptomycin resistance, *sr*×*sr* crosses have been carried out using nine *sr* mutants of independent origin. A total of between 700 and 800 prototroph colonies from these were examined for streptomycin response. Of the crosses none gave rise to *ss* (or *sd*) prototrophs, from which it may be assumed that most of the mutations to the *sr* form, and possibly all of them, take place at the same locus.

sd CROSSES

Reversed crosses of *ss*×*sd* have been made using lines Y-40 and Y-53 (see table 3). The bulk of the recombinants from these, as in the *ss*×*sr* crosses, resembled the B^+ M^+ (Y-53) parent with respect to streptomycin response. However, no *sd* segregants were recovered when the *sd* parent was derived from the B^- M^- line. This dissimilarity in the crossing behavior of *sd* and *sr* forms could be due to differences either in the segregation of *sd* and *sr*, or in the recovery of the products of segregation. Since the parental *sd* forms have growth factor requirements in addition to stated ones, the second of these interpretations is quite possible.

It should be noted also that *sd*×*sd* crosses have been made, using four independently obtained mutant lines. These crosses have yielded recombinant colonies only when streptomycin was present, and all the colonies tested were *sd*.

sr × *sd* CROSSES

If mutations to *sr* and to *sd* involve different gene loci, then *sr*×*sd* should give rise to a proportion of *ss* colonies. Tests of this nature have already been used to distinguish between allelic and non-allelic changes affecting phage resistance, lactose fermentation, and maltose fermentation (E. LEDERBERG

TABLE 3

Segregation of streptomycin dependence.

CROSS	PARENT STRAINS		STREPTOMYCIN ABSENT				STREPTOMYCIN PRESENT			
	Y-40	Y-53	COLONIES TESTED	PERCENT			COLONIES TESTED	PERCENT		
				ss	*sr*	*sd*		*ss*	*sr*	*sd*
A	*ss* ×	*sd*	22	100	0	0	565	0	0	100
B	*sd* ×	*ss*	505	100	0	0	0	0	0	0

1948, and J. LEDERBERG 1947, 1948, and 1949) and have yielded what appear to be valid conclusions.

For the present test, reversed *sr* × *sd* crosses were made using mutant forms derived from lines Y-40 and Y-53. To eliminate any *ss* cells which might arise by further mutation the parents were grown in broth containing 1000 units of streptomycin per ml, and were then crossed by plating in the usual manner. Table 4 shows the types of descendent colony obtained.

Where the crosses were made in the presence of streptomycin, and growth factor recombinants of either parental type with respect to streptomycin

TABLE 4

Test of allelism of the genes for streptomycin resistance and streptomycin dependence.

CROSS	PARENT STRAINS		STREPTOMYCIN ABSENT				STREPTOMYCIN PRESENT			
	Y-40	Y-53	COLONIES TESTED	PERCENT			COLONIES TESTED	PERCENT		
				ss	*sr*	*sd*		*ss*	*sr*	*sd*
A	*sr*	*sd*	417	1.2	98.8	0	300	0	6.3	93.7
B	*sd*	*sr*	160	0	100	0	158	0	100	0

response were thus enabled to grow, segregation of the *sr* and *sd* mutant characters was similar to that observed in the *sr*×*ss* and *sd*×*ss* crosses shown in tables 1 and 3, thus: (1) with Y-40 as the *sr* parent approximately 6 percent of the colonies were *sr*, and (2) with Y-40 as the *sd* parent *sd* colonies were absent.

Where crosses were made in the absence of the drug the bulk of the growth factor recombinants were *sr*, although a few *ss* colonies (5 out of a total of 417 in cross A of table 4) were found. In a subsequent set of experiments involving similar numbers of tests no *ss* colonies were obtained. The *ss* colonies, however, represent a valid observation despite this irregularity in their appearance and it is with their interpretation that we are primarily concerned. Had the proportion been larger it would have indicated that *sr* and *sd* were mutants of separate gene loci. But in view of the small number of *ss* colonies they could have been the result either of rare recombinations between the *sr* locus and a closely linked *sd* locus, or of mutation from *sd* to *sd/ss*.

Mutations of this kind are known to occur during growth and the precaution of growing the parent lines in high concentrations of streptomycin prior to plating would not prevent them from taking place on the plates. In all crosses the surface of the agar was covered with a confluent bacterial growth which could be seen under a high power dry objective, and in some experiments was visible to the naked eye. The extent of this growth was such that appreciable mutation from *sd* to *sd/ss* would be expected, and the products of these mutations would be at a selective advantage when streptomycin was absent. Thus, although the possibility of rare recombination between *sr* and *sd* cannot be entirely eliminated, it is more probable that *sr* and *sd* are alleles of a single locus and that the *ss* colonies arose by mutation.

sd/ss AND *sd/sr* CROSSES

Mutation from dependence to sensitivity and to resistance (*sd* to *sd/ss* and to *sd/sr*) might occur either by further change of the *sd* gene, or by mutation at some other locus. If the latter is the case, a proportion of *sd* segregants would be expected on crossing the double mutant with a sensitive or a resistant line. This test has been applied to four such forms (Y-40/*sd/ss*, Y-40/*sd/sr*, Y-53/*sd/ss*, and Y-53/*sd/sr*), each of them being crossed with *ss* and with *sr* lines of the appropriate kinds, both in the absence and in the presence of streptomycin.

Of the four double mutants tested, three gave no *sd* segregants (data not shown) indicating that the second mutation took place in the same or in a closely linked locus. From the remaining one, a Y-53/*sd/sr* mutant, an appreciable proportion of *sd* (or to be more precise, potentially *sd*—see below) growth factor recombinants was recovered (see table 5). Segregation in the latter case was exceptional, however, and will be described in detail.

TABLE 5

Crosses with an sd/sr mutant from which potentially sd segregants have been obtained

CROSS	PARENT STRAINS			STREPTOMYCIN ABSENT					STREPTOMYCIN PRESENT				
	Y-40		Y-53	COLONIES TESTED	PERCENT				COLONIES TESTED	PERCENT			
					ss	*sr*	*sd*	POTENTIAL *sd*		*ss*	*sr*	*sd*	POTENTIAL *sd*
A	*ss*	×	*sd/sr*	214	15	0	0	85	86	0	0	0	100
B	*sr*	×	*sd/sr*	218	0	13	0	87	152	0	80	0	20

With all previous crosses the streptomycin response of the majority of the descendents has been similar to that of the B^+ M^+ parent, but with the crosses shown in table 5 the response of the Y-53 parent (i.e. resistance) was not transmitted as such. Instead there appeared among the recombinant colonies a class which was sensitive to high concentrations of streptomycin, but which gave rise to normal *sd* cultures if incubated for two or three days in a synthetic medium containing streptomycin. Growth of this potentially dependent form was inhibited on complete media such as E.M.B. both in the absence and in the presence of streptomycin, although the *sd*'s derived from it behaved normally.

Where crosses were made in the absence of streptomycin the majority of the prototrophs were of the potentially dependent type, the remainder resembling the Y-40 parent. These latter included an abnormally high proportion of lactose positive colonies (63 percent as against the usual 36), whereas the potential *sd*'s were normal in this respect. The difference is statistically significant ($\chi^2=35.1$ for a 2×2 comparison) and represents the only instance of an apparent linkage between streptomycin response and lactose fermentation in any of our crosses.

The anomalies associated with this cross (the development of potential *sd*'s, the non-recovery of Y-53 resembling forms, and the altered Lac^+:Lac^- ratio in the Y-40 resembling descendents) suggest that the *sd/sr* parent con-

tained a number of modifier mutations which adversely affected the survival of some of the recombination types. As the original *sd/sr* mutant strain grew poorly on nutrient agar slants, and gave rise to numerous large colony variants, the accumulation of a number of modifier mutations would not be surprising.

However, for present purposes it is more important that *sd* forms were obtained, even if indirectly, from crosses with an *sd/sr* parent. The fact that recombinants from this cross could revert to *sd*, although the parent *sd/sr* could not, indicates that mutation from *sd* to *sd/sr* must have occurred at a modifier gene locus. (A similar case of modifier mutation has been noted by HOULAHAN and MITCHELL 1947, in Neurospora.)

DISCUSSION

Of the nine *sr* and the four *sd* lines studied, all appear to have arisen by change at a single gene locus. These numbers by no means exclude the possibility of mutations at other loci giving rise to a proportion of the resistant or dependent forms. Nor is it entirely certain that *sr* and *sd* are not "pseudoalleles," and that crossing over between them is too rare to be detected with certainty by the present methods. (For discussions of pseudoalleles see MCCLINTOCK 1944, STEVENS 1948, and GREEN and GREEN 1949.) However, it seems most likely that *sr* and *sd* are alleles of a single locus and, since a considerable range of *sd* forms has been observed, that there is a multiple allelic series at this locus the precise extent of which has not as yet been determined.

That this series is in all probability very extensive is suggested by a number of considerations. One is that the dependent forms differ among themselves, not only in the degree of their dependence, but also with respect to the compounds other than streptomycin which will supply their requirements (DEMEREC 1950). A second is that the double mutants derived from the dependent forms (*sd/ss* and *sd/sr*), an appreciable proportion of which appear to arise through a second mutation at the original locus, form a more or less continuous series with respect to degree of resistance. In addition, two broad categories of mutation (from sensitivity to the lower grades of resistance, and from dependence to the lower grades of dependence coupled with incomplete resistance) have not so far been studied in detail. However, preliminary work in this laboratory indicates that the partially resistant forms of *E. coli* strain *B/r* (those capable of growing in streptomycin concentrations of 16, 32, 64, and 128 units per ml) mutate to the fully resistant type at about 10 to 20 times the normal rate. This would suggest that the same locus is involved in both types of change.

It therefore appears that the streptomycin locus can mutate to a number of different categories of allele, and that each category may contain a range of mutant types. Thus the mutation pattern would seem to have what could be termed a "coarse" and a "fine" structure, and to be as complex as any yet studied.

SUMMARY

1. Streptomycin resistant (*sr*) and dependent (*sd*) mutants derived from the

sexually fertile *E. coli* strain K12 have been crossed with the sensitive (*ss*) form and with each other.

2. The streptomycin response of the bulk of the progeny resembled that of the biotin and methionine independent parent, resistance and dependence being inherited similarly in this respect. Streptomycin resistance is linked with the fermentations of maltose, xylose, D-galactose, and L-arabinose, but not in a manner implying linear arrangement of the genes concerned. No linkage was observed between streptomycin resistance and lactose fermentation, phage T1 resistance, or thiamin requirement.

3. Resistance and dependence are inherited as if controlled by allelic forms of the same gene locus.

4. Of four double mutants derived from the dependent form by further change to sensitivity (*sd/ss*) and to resistance (*sd/sr*), three (two sensitive and one resistant) behaved on crossing as if both mutations had occurred at the same locus. The remaining (resistant) double mutant behaved as if the second of the two changes had been the result of mutation at a modifier locus.

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INBREEDING AND HOMOZYGOSIS IN BEES*

JAMES F. CROW AND WILLIAM C. ROBERTS
University of Wisconsin, Madison, Wisconsin

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TWO discoveries in recent years have made controlled mating in the honey bee (*Apis mellifera* L.) a practical possibility. These are (1) suitable techniques for artificial insemination, and (2) the use of carbon dioxide to stimulate egg-laying by virgin and artificially inseminated queens. (For techniques and references, see MACKENSEN and ROBERTS 1948.) In controlled breeding experiments it is desirable to have formulae for estimating the changes in homozygosity and relationship which follow various systems of mating.

The genetic consequences of various kinds of inbreeding procedures have been worked out by JENNINGS (1912, 1914, 1916), ROBBINS (1917), and especially by WRIGHT (1921, 1933). But because of ploidy differences in male and female some modification is required if the formulae are to be applicable to bees. KALMUS and SMITH (1948) have recently reported on the amount of increase in homozygosity to be expected under three systems of mating. In this article we shall, using WRIGHT'S methods, verify and extend these results, and give procedures for determining coefficients of inbreeding and relationship from irregular bee pedigrees. The formulae are, of course, applicable to Habrobracon or other haploid-diploid organisms.

Since the male bee is haploid, the genetic composition of every gamete produced by a drone is the same and is identical to that of the unfertilized egg from which the drone developed. Therefore, the correlation between the gamete giving rise to a male and a gamete produced by that male is one. With this slight modification in the value of the coefficients in a path diagram, the procedures devised and used by WRIGHT (1921, 1933) become directly applicable. The situation is analogous to matings involving sex-linked or homozygous autosomal loci in diploids and in some cases the results have already been worked out by WRIGHT.

GENERAL FORMULAE

The symbols and basic formulae used here as well as the method of diagramming mating systems are taken directly from the work of WRIGHT (1921a, 1921b, 1933, 1934). The reader is referred to these papers for a general discussion of WRIGHT'S method of path coefficients and its application to breeding problems. The formulae relevant to this discussion are as follows and refer to the diagrams in the figures:

(1) Squared path coefficient, zygote to gamete $b^2=(1+f')/2$

* Paper No. 417 from the Department of Genetics, University of Wisconsin, in cooperation with U.S.D.A., Agricultural Research Administration, Bureau of Entomology and Plant Quarantine.

(2) Squared path coefficient, gamete to zygote $a^2=1/2(1+f)$
(3) Correlation between uniting egg and sperm $f=1-2p$
(4) Proportion of heterozygous loci $p=(1-f)/2$

Symbols with primes refer to the previous generation. The formula for p assumes that, with random mating, $p=.5$, which would be true in the special case of two alleles with equal frequency. If the proportion of heterozygosity in a randomly mating population is some other value, p should be multiplied by twice this value to give the true proportion of heterozygosity.

MOTHER-SON MATING

In this procedure the unmated queen is first stimulated to lay unfertilized eggs. Later she is inseminated with sperm from a drone which has developed from one of these eggs, and the whole process is repeated with the females that have developed in the next generation. KALMUS and SMITH (1948) have called the step from one female to the next a "double generation" and we shall follow that terminology here.

From figure 1 and formulas (1) and (3)

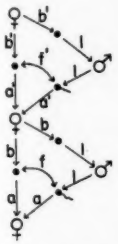

FIGURE 1. Mother-son mating.

$f=b^2=(1+f')/2$
$p=p'/2$

The proportion of heterozygosity in females is halved each double generation as has been shown by KALMUS and SMITH. This system of mating is mathematically equivalent in a double generation to a single generation of self-fertilization in diploid organisms.

With present techniques of artificial insemination of bees the best results are obtained by pooling the semen from three or four drones for a single insemination of a queen and repeating the process after 48 hours. Fortunately this does not change the rate of increasing homozygosity under this system of mating. As long as all the males used are sons of the queen which they are used to inseminate the proportion of heterozygosity is reduced by 50 percent each double generation (equivalent to 29.3 percent each single generation).

BROTHER-SISTER MATING

From the diagram in figure 2

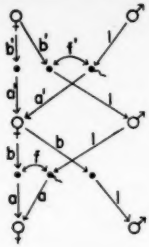

FIGURE 2. Brother-sister mating.

$f = ba'b'^2 + ba'f' = 1/4 + f'/2 + f''/4$

$p = p'/2 + p''/4 = p' - p''/8$

This formula is equivalent to the formula, $h = h' + (1 - h'')/8$ where h is the proportion of homozygous loci, derived by KALMUS and SMITH by an entirely different procedure. Also the mathematically equivalent case, that of brother-sister mating with sex-linked genes was originally worked out by WRIGHT (1933). The limiting rate of change per generation (obtained by setting $p/p' = p'/p'' = x$ and solving for $1 - x$) is 19.1 percent.

As in the case of self fertilization the use of pooled semen from several brother drones does not alter these results.

AUNT-NEPHEW MATING

From figure 3

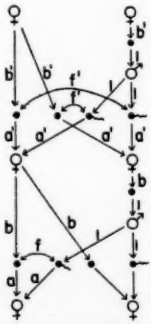

FIGURE 3. Aunt-nephew mating.

$f = b^2a'^2b'^2 + b^2a'^2 + 2b^2a'^2f' = 3/8 + f'/2 + f''/8$

$p = p'/2 + p''/8$

This is equivalent to the formula, $h = 3h'/4 + (9 - h'')/32$, obtained by another procedure by KALMUS and SMITH (1948). The limiting percentage reduction in heterozygosity is 31.7 percent per double generation, or 17.0 percent per single generation.

In order for the heterozygosity to be reduced at this rate it is necessary that a single male be used to inseminate the queen. This precludes the use of pooled semen which with present techniques is necessary for a high percentage of fertilized eggs and therefore makes this system of mating less useful than it would be otherwise.

COUSIN MATING

In bees there is no distinction between cousin and double cousin mating because of the fact that the male has only one parent. A system of continuous

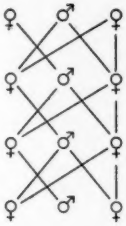

FIGURE 4. A system of continuous cousin mating.

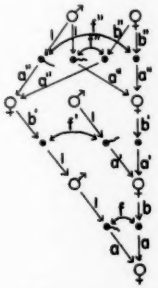

FIGURE 5. Cousin mating.

cousin mating is diagrammed in figure 4. From the path diagram in figure 5,

$$f = ba'f' + 2(a'b\ b'^2a''^2f) + a''^2b'^2a'b + a''^2b'^2a'bb''^2$$
$$= 3/16 + f'/2 + f''/4 + f'''/16$$
$$p = p'/2 + p''/4 + p'''/16$$

This is the same formula as that obtained by WRIGHT for mating of half-brothers and sisters in diploid organisms. The limiting rate of decrease of heterozygosity (obtained by setting $p/p' = p'/p'' = p''/p''' = x$ and solving for $1-x$) is 13 percent per generation as compared with eight percent for double first cousins in diploids.

In this system of mating, as in aunt-nephew mating, it is necessary to use sperm from only a single drone if this analysis is to be applicable.

UNCLE-NIECE MATING

Homozygosity is attained at a considerably slower rate with uncle-niece mating than with aunt-nephew mating in bees. From figure 6,

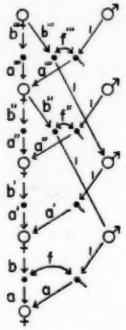

FIGURE 6. Uncle-niece mating.

$$f = ba'b'a''b''^2 + ba'b'a''f'' + ba'b'' ''^2a'' 'b'' + ba'f'' 'a'' 'b''$$
$$= 1/4 + f''/4 + 3f'' '/8 + f'' ''/8$$
$$p = p''/4 + 3p'' '/8 + p'' ''/8$$

This formula assumes that the female used to start the inbreeding is herself the offspring of an uncle-niece mating. If she is the result of random mating the heterozygosity in successive generations is 4/8, 7/16, 12/32, 23/64, 41/128, etc. The limiting rate of decrease in heterozygosity is 9.6 percent per generation as compared with 17.3 percent for aunt-nephew mating.

In this system pooled semen from several males may be used without upsetting the calculations as long as they are sons of the same queen.

REPEATED BACKCROSSING TO A MALE

In the process of artificial insemination the male is killed so it is not possible to use a male for successive mating. However, it is possible, though not practical at present, to inseminate a female, allow her to lay fertilized eggs, and use sperm recovered from her spermatheca to inseminate her daughter. If this process could be kept up for several generations and semen from only a single male were used each time, it would be equivalent to successive backcrosses to a homozygous parent in diploid organisms. This case has been treated by WRIGHT (1921) who showed that $p = p'/2$. The heterozygosity is reduced by one-half each single generation. If techniques are developed making this a practical procedure it will be the most rapid inbreeding system possible in bees. At present it is only of theoretical interest.

BACKCROSSING TO A FEMALE

An additional mating system that is often useful in bee breeding is crossing successive generations of females with drones from a single female. This

is illustrated by the first three generations of the pedigree in figure 8. This is equivalent to repeated backcrossing to the original female with the drones acting as successive gametes. The situation then becomes identical to the same mating system in diploids which has been worked out by JENNINGS (1916) and WRIGHT (1921). The heterozygosity formula is:

$$p=1/8+p'/2$$

and if the initial percentage of heterozygosity is assumed to be 50 percent the series 3/8, 5/16, 9/32, 17/64, etc. is obtained.

This series does not approach 0 as a limit, but rather 1/4 as may be seen by setting $p=p'$. Nevertheless, the increase in homozygosity in the first few generations is quite rapid, being initially the same as brother-sister mating. The chief merit of this system of mating comes from the fact that females mature faster than males. The time from egg to time of mating for queens is about 22 days and for drones about 38 days. For this reason heterozygosity is reduced more rapidly at first by this system than by brother-sister mating. Also this procedure allows repeated backcrossing to an outstanding queen.

The use of pooled semen does not affect the accuracy of the calculations in this system.

CONCLUSIONS CONCERNING INBREEDING SYSTEMS

The formulae from the previous sections together with the proportion of heterozygosity in successive generations under each system of mating are given in table 1. These proportions are shown graphically in figure 7. The

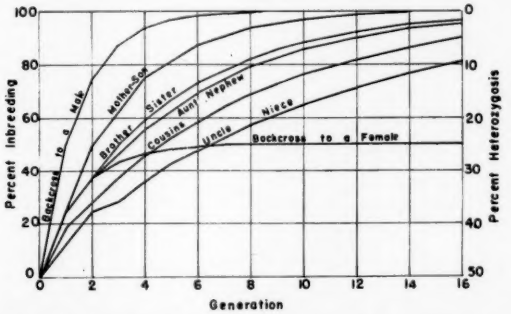

FIGURE 7. Percentage of inbreeding (100 f) and percentage of heterozygosis (100 p, assuming the initial value to be 50 percent) in successive generations of various systems of inbreeding.

initial value of the heterozygosity is assumed to be 50 percent, which would be true for a randomly mating population with the two alleles equally frequent. If the initial fraction is not 50 per cent multiply each figure in the table by twice this fraction.

Among those systems of mating which are practical with present techniques the most rapid decrease in heterozygosity is by mother-son mating. Next most rapid over a long period is brother-sister mating. For a few generations,

TABLE 1

Change in heterozygosity under various systems of mating.

SYSTEM OF MATING	HETEROZYGOSITY FORMULA	APPROXIMATE DECREASE IN HETEROZYGOSITY PER SINGLE GENERATION %	PROPORTION OF HETEROZYGOUS LOCI IN SUCCESSIVE GENERATIONS (STARTING WITH .500)									
			0	1	2	3	4	5	6	10	16	∞
Backcross to ♂	$p=\frac{p'}{2}$	50	.500	.250	.125	.062	.031	.015	.008	.000	.000	0
Mother-son	$p=\frac{p'^*}{2}$	29.3	.500	—	.250	—	.125	—	.062	.015	.002	0
Brother-sister	$p=\frac{p'}{2}+\frac{p''}{4}$	19.1	.500	.375	.312	.250	.203	.164	.133	.057	.016	0
Aunt-nephew	$p=\frac{p'}{2}+\frac{p''^*}{8}$	17.4	.500	—	.312	—	.219	—	.148	.069	.022	0
Cousins	$p=\frac{p'}{2}+\frac{p''}{4}+\frac{p'''}{16}$	13.0	.500	.406	.359	.312	.271	.236	.206	.118	.051	0
Uncle-niece	$p=\frac{p''}{4}+3\frac{p'''}{8}+\frac{p''''}{8}$	9.6	.500	.438	.375	.359	.320	.285	.262	.175	.095	0
Backcross to ♀	$p=\frac{1}{8}+\frac{p'}{2}$	—	.500	.375	.312	.281	.266	.258	.254	.250	.250	.250

* Formula given for double generations.

because of the shorter period from egg to time of mating in females, backcrossing to a female through successive matings with her sons is more rapid. With any of these three systems pooled semen from brother drones may be used without changing the formulae.

All other practical systems are considerably slower than these. However, if it becomes a practical procedure to make successive back crosses to a male by collecting semen from the spermatheca of previously fertilized females, this will be the most rapid system of all. The heterozygosity would be decreased by 50 percent each generation and the generation cycle would be short because of the short life cycle of females.

If it is desired to compute the probability that a bee, after a certain number of generations of inbreeding, will be homozygous for N independent factors or for a certain chromosome length, the formulae developed by HALDANE (1936) and applied by KALMUS and SMITH (1948) may be used.

COEFFICIENTS OF INBREEDING AND RELATIONSHIP

Since it is usually not possible to adhere to a strict system of mating for a great length of time, it is necessary to assess the consequences of inbreeding that follow the irregular patterns so often observed in pedigrees. For such purposes WRIGHT'S (1922) coefficients of inbreeding and relationship are regularly used. With very slight modifications these formulae are directly applicable to bee pedigrees.

The path diagram is drawn in the usual way and the inbreeding coefficient is computed by the formula

$$F=\Sigma(1/2)^{n-1}(1+F_A)$$

where n is the number of generations from the individual in question to a common ancestor and back again through the other parent. However, all steps involving a male are counted as 1/2 rather than 1. F_A is the coefficient of inbreeding of the common ancestor, considered to be 0 in a male.

Exactly the same modification is made in the formula for coefficient of relationship

$$R_{xy} = \sum (1/2)^n \frac{1 + F_A}{\sqrt{(1 + F_x)(1 + F_y)}}$$

where n is the number of generation steps (again counting all steps involving a male as half a step) from one individual through a common ancestor to the other. F_x and F_y are the inbreeding coefficients of the individuals whose relationship is being measured. As in the previous formula the inbreeding coefficient of a male is considered to be 0.

Figure 8 shows a pedigree of bees from our stocks. The inbreeding coefficients of the various females in the pedigree are as follows:

C. $F=(1/2)^{3-1}=.25$
D. $F=(1/2)^{3-1}+(1/2)^{4-1}=.375$
E. $F=(1/2)^{3-1}(1+.25)+(1/2)^{4-1}+(1/2)^{5-1}=.5$

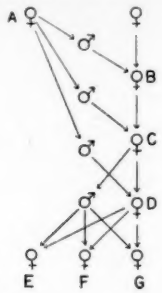

FIGURE 8. A bee pedigree.

Thus the sisters E, F, and G have on the average only one-half as many heterozygous loci as if they had been produced by random mating.

The relationship coefficient between E and G is

$$R = \frac{1}{\sqrt{(1+.5)(1+.5)}}\left[(1/2) + (1/2)^2(1+.375) + 2(1/2)^3(1+.25) + 2(1/2)^4 + 2(1/2)^5\right] = .896.$$

In the first term in brackets the father is the common ancestor, in the second term D, in the third C, and in the fourth and fifth A.

It is interesting to note that in bees full sisters have a coefficient of relationship of .75 if the female parent is not inbred as compared with .50 for diploid organisms.

If pooled semen is used the formulae for inbreeding and relationship coefficients still apply provided that the drones are all brothers and that the female thus inseminated is represented by only one daughter in the pedigree.

An alternative, and in many cases simpler, procedure for determining inbreeding and relationship coefficients is to draw the pedigree diagram omitting the males entirely, regarding them as equivalent to gametes from their mother. With the pedigree drawn in this way the usual formulae of WRIGHT are directly applicable. This simple method cannot be used if a male is represented by more than one daughter in the pedigree.

Recent work of MACKENSEN (unpublished) indicates that the Habrobracon type of multiple allelic sex determining system is at work in bees, except that homozygous diploids are lethal. This means, of course, that there would be strong selection for heterozygosity of genes closely linked to the sex determining locus and that the increase in homozygosity of such genes would be much slower in any inbreeding system.

SUMMARY

Formulae are given for determining the change in heterozygosity with various systems of inbreeding in honey bees. These formulae and numerical data are in table 1.

By making a slight modification (counting all steps involving a male as only half a generation) in WRIGHT'S formulae for coefficients of inbreeding and relationship these become applicable to bee pedigrees.

ACKNOWLEDGMENT

We are indebted to Professor ARTHUR B. CHAPMAN for many helpful suggestions.

NOTE ADDED IN PROOF: We have learned that a similar article by POLHEMUS, LUSH, and ROTHENBUHLER in which many of the same conclusions are reached will appear in an early issue of the Journal of Heredity.

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INHERITANCE OF AUDIOGENIC SEIZURE SUSCEPTIBILITY IN THE MOUSE

JOHN L. FULLER, CLARICE EASLER AND MARY E. SMITH
Division of Behavior Studies, Roscoe B. Jackson Memorial Laboratory, Bar Harbor, Maine

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HALL (1947) has reported a remarkable difference between dba and C57 black mice in their susceptibility to audiogenic seizures. When dba mice are placed in a metal tub and stimulated by the sound of a doorbell, the majority undergo violent tonic-clonic seizures which are usually fatal. The incidence of such seizures in the C57 black strain is very low. These convulsions appear to be similar to audiogenic seizures occurring in rats, which have been recently discussed by FINGER (1947). Similar convulsions have been reported in Peromyscus (DICE 1935; WATSON 1939) where susceptibility has been considered due to recessive genes. In 1949 WITT and HALL attributed seizure susceptibility in the house mouse to a single dominant gene which they called *As*. This hypothesis was based upon the results of the F_1, F_2 and the two backcross generations. Only their "critical backcross" of $F_1 \times$ C57 bl non-reactors by C57bl failed to accord with their single dominant gene hypothesis. Twenty-five percent of these animals underwent mild convulsive behavior which the authors attributed to minor modifying genes. GINSBURG, MILLER and ZAMIS (1950) have postulated two or more non-dominant factors, including a single major gene essential for seizure susceptibility.

The clearcut strain difference makes these animals admirably suited for investigations of physiology of convulsions, and the physiological genetics of susceptibility. GINSBURG and HOVDA (1947) in the course of studying the metabolic differences between strains, noted that one strain of dba's recovered from seizures more readily than the regular Jackson Laboratory stock of dba's. These animals were descended from a female which had developed in the uterus of a C57 bl female following an ovum transfer. They suggested that a nongenic maternal influence might affect recovery. The experiments described in this paper were initiated to test this hypothesis by comparing reciprocal crosses. The preliminary results were not in accordance with the single dominant gene hypothesis, and a series of experiments was initiated on the factors producing variability in the risk of convulsions in hybrids.

METHODS

The subjects of this experiment were C57 black subline 6 Jax mice descended by brother-sister matings from WITT and HALL's original strain. The dba mice were of subline 2 and had been inbred for over 50 generations. WITT and HALL used dba subline 1, and it has been shown that the authors' subline has an even higher susceptibility than HALL's original stock.

The stimulation method used was identical to that of WITT and HALL except that behavior observations were not made for a two-minute period following bell ringing, and each animal, provided it survived that long, was

exposed on five successive days (instead of four) to two minutes of bell ringing. The mice were 30 days of age on the first trial day except for F_2 animals which were started on Mondays at an age of 29 to 35 days.

Our index of seizure susceptibility differs from that of WITT and HALL. These investigators classified each animal as a "reactor" or "non-reactor." A "reactor" was defined as an animal which convulsed on any one of its four trials. Their tables show 93.3 percent of the dba stock to be "reactors," and 94.7 percent of the C57 black stock to be "non-reactors," while the F_1 mice included 94.5 percent of reactors. These figures indicate that the convulsion phenotype does not always follow the genotype, and that a classification of genotypes on their basis cannot be expected to be accurate to better than ± 5 percent. It seems to be more satisfactory to define seizure susceptibility in terms of the risk of an induced convulsion during a standard exposure. This risk cannot be determined on one individual, but it can be calculated for populations of different genotypes. Since the percentage of convulsions is usually highest on first exposure, the first exposure seizure risk is the best single index of susceptibility. In estimating this value all convulsions of any degree of severity are included, but preconvulsive activity, such as hopping or wild circling, is not. The percentage of seizures among survivors of the first trial on successive trials is of physiological and genetic interest, particularly when dealing with genetically heterogeneous groups such as the F_2, F_3 and backcrosses.

RECIPROCAL CROSS AND SEX DIFFERENCES

The principal results of this investigation are summarized in table 1, which gives the percentage of convulsions and of deaths for each group of mice studied. No statistically significant differences have been found between reciprocal crosses and they have been grouped together in all summarizing tables. There are nine possible pairings of male and female subjects with the same genetic background. If the comparison is based upon the percentage of "reactors" (WITT and HALL's criterion), males have a higher percentage in three pairings, females in three, and the remaining three cases are equal. If the comparison is based upon first trial seizure risk, the males are higher in five cases, females in two, and two are equal. The most extreme sex differences are found in the $F_1 \times$ C57 black backcross and F_1 hybrids. In the latter group females showed a higher susceptibility than males. This particular group of mice appears to be exceptional and will be discussed below. In fact, a repeat sample of F_1's included on the last line of table 1 shows a strong reversal of the sex difference. The effect of sex on susceptibility appears to be influenced by the genotype of the individual. It is unimportant in genotypes with very high or very low susceptibility, and influential in genotypes of moderate susceptibility.

THE SINGLE DOMINANT GENE HYPOTHESIS

If the sexes and reciprocal crosses are combined, as in table 2, it is possible to compare these results with those of WITT and HALL. The two parent strains

TABLE 1

Incidence of convulsions (C) and death (D) from convulsions in dba, C57b1, and hybrids

FEMALE P	MALE P	SEX	N	PERCENT CONVULSERS	TRIAL 1			TRIAL 2			TRIAL 3			TRIAL 4			TRIAL 5			TRIALS 1–5			D/C ×100	% SURVIVORS
					N	%C	%D	N	%C	%D	N	%C	%D	N	%C	%D	N	%C	%D	N	%C	%D		
dba	dba	F	41	100	41	98	85	6	83	33	4	100	100							45	96.1	80.4	87.0	0.0
dba	dba	M	54	100	54	100	87	7	100	57	3	33	33	2	50	50	1	0	0	67	94.0	79.1	84.7	2.0
F_1	dba	F	59	97	59	90	54	27	33	19	22	41	5	21	48	5	20	50	5	148	60.8	26.3	43.2	32.3
F_1	dba	M	69	93	69	93	61	27	70	22	21	57	10	19	58	10	17	47	0	152	74.3	33.5	45.1	24.6
dba	F_1	F	31	94	31	87	65	11	55	27	8	38	0	8	63	13	7	29	0	65	66.2	37.0	55.8	22.6
dba	F_1	M	32	100	32	97	47	17	59	30	12	75	8	11	73	9	10	40	20	82	75.7	29.3	28.7	25.0
dba	C57	F	25	76	25	32	16	21	10	0	21	33	19	17	47	12	15	40	0	99	31.3	10.1	32.0	60.0
dba	C57	M	25	52	25	20	12	22	18	14	19	26	5	18	22	6	17	29	0	101	22.3	7.9	35.4	68.0
C57	dba	F	25	84	25	48	20	20	20	10	18	56	6	17	53	12	15	60	13	104	45.8	12.8	27.9	52.0
C57	dba	M	25	64	25	28	8	23	26	13	20	45	10	18	22	0	18	22	6	94	29.9	7.7	25.7	68.0
F_1	C57	F	49	37	49	18	10	44	2	2	43	5	2	42	2	0	42	14	7	220	8.2	4.1	50.0	79.6
F_1	C57	M	35	37	35	29	20	28	11	4	27	11	7	25	4	0	25	8	0	140	13.5	7.1	52.5	71.5
C57	F_1	F	37	24	37	16	14	32	9	3	31	0	0	31	3	3	30	0	0	161	6.2	4.3	71.0	81.2
C57	F_1	M	30	37	30	30	23	23	4	4	22	5	0	22	9	5	21	5	0	104	11.8	7.6	64.3	70.0
F_1	F_1	F	55	69	55	60	29	39	41	5	37	30	0	37	32	3	36	31	6	204	40.7	10.3	25.3	61.8
F_1	F_1	M	57	70	57	60	40	33	27	9	30	17	3	29	24	10	26	12	0	175	33.1	17.1	51.7	45.6
C57	C57	F	25	0	25	0	0	25	0	0	25	0	0	25	0	0	25	0	0	125	0	0	—	100.0
C57	C57	M	25	0	25	0	0	25	0	0	25	0	0	25	0	0	25	0	0	125	0	0	—	100.0
(dba)†	(C57)	M	73	79*	79	74	51	17*	6*	0*	17*	12*	6*	16*	13*	0*	16*	31*	0*	104*	35.6*	21.2*	59.6*	42.1*
(C57)	(dba)	F																						

* Based upon a subsample of 38 F_1 animals.

† This is referred to as the "repeat" F_1.

TABLE 2

Summary of selected results by genetic groups.

GROUP	N	PERCENT CONVULSERS 5 TRIALS	PERCENT* "REACTORS" WITT & HALL 4 TRIALS	TRIAL 1		TRIAL 1 D/C	PERCENT SURVIVORS 5 TRIALS
				% C	% D		
dba	96	100	93.3±4.7	99	86±3.5	87±3.5	1
F_1×dba	191	95 ±1.6	90.9±6.1	92±2.0	57±4.6	62±3.7	27 ±3.2
F_1 "original"	100	68 ±4.7	90.5±3.3	32±4.7	14±3.5	44±8.8	62 ±4.9
F_1 "repeat"	73	79†±6.6	90.5±3.3	74±4.9	51±5.8	69±6.3	42†±8.0
F_2	112	70 ±4.3	77.3±5.0	60±4.6	35±4.5	58±6.0	53 ±4.7
F_1×C57bl	151	34 ±3.8	52.8±6.0	23±3.4	16±3.0	70±7.7	76 ±3.5
C57 bl	50	0	5.3±3.6	0	0	0	100

* Data from WITT and HALL (1949)

† Based upon a subsample of 38 cases.

which were used differ more widely than those of WITT and HALL, and all hybrids except the F_1×dba have a lower percentage of "reactors" than these authors obtained. It should also be noted that hybrids which would be expected to behave like dba's under the single dominant gene hypothesis (F_1×dba and F_1) actually differ considerably, particularly if death-convulsion ratios and percentage of survivors of five trials are taken into consideration.

Both the "original" and "repeat" samples of F_1 are intermediate in susceptibility between the parental strains. It is probable that the repeat group is more representative of the total F_1 population. The original F_1 sample is exceptional in having a higher susceptibility in females than in males, in not showing the highest seizure incidence on the first trial, and in not fitting into the progression of susceptibility indices. If the F_1 repeat group replaces the original sample, indices of susceptibility are seen to decrease regularly in relation to the proportion of dba genes contained in each group. The single dominant gene hypothesis may be formally tested by calculating χ^2 for the F_2 and F_1×C57bl groups on the assumption that all animals carrying this gene will convulse within five trials and 99 percent of them will convulse on the first trial.

The values marked with asterisks are significant at better than the 1 percent level, so that the dominant gene hypothesis may be rejected for this particular cross.

GROUP	CONVULSE WITHIN 5 TRIALS				CONVULSE ON FIRST TRIAL		
	N	EXPECTED	OBSERVED	χ^2	EXPECTED	OBSERVED	χ^2
F_2	112	84	78	1.72	83	66	13.41*
F_1×C57bl	151	75.5	51	14.9*	75	35	43.7*

We may now examine the evidence as it relates to the number of genes involved. Will a single gene producing high susceptibility in homozygous animals and moderate susceptibility (74 percent) in heterozygous animals

explain the results? In calculating expected values under this assumption the F_1 repeat group is taken as the standard for the heterozygote. The calculations may be summarized as follows:

	GENOTYPES	FIRST TRIAL SEIZURE RISK CALCULATED	OBSERVED
$F_1 \times$dba	1/2 *AA*, 1/2 *Aa*	(99+74)/2=86.5	92±2.0
F_2	1/4 *AA*, 1/2 *Aa*, 1/4 *aa*	(99+2(74)+0)/4=61.8	60±4.6
$F_1 \times$C57bl	1/2 *Aa*, 1/2 *aa*	(74+0)/2=37.0	23±3.3
		CALCULATED TOTAL CONVULSIONS	OBSERVED
$F_1 \times$dba	1/2 *AA*, 1/2 *Aa*	(100+79)/2=89.5	95±1.8
F_2	1/4 *AA*, 1/2 *Aa*, 1/4 *aa*	(100+2(79)+0)/4=64.5	70±4.6
$F_1 \times$C57bl	1/2 *Aa*/ 1/2 *aa*	(79+0)/2=39.5	34±3.9

Except for the first trial seizure risk for the $F_1 \times$C57, the calculated and observed risks do not differ more than might be explained by errors of random sampling and the occurrence of modifying genes. The assumption of a single major partially-dominant convulsing gene is not contraindicated by these data.

As WRIGHT (1934) has pointed out, however, the occurrence of expected ratios in the F_1, F_2, and backcross generations is not a certain proof of single gene control. An attempt was made to utilize WRIGHT'S procedure for estimation of the number of genes involved, by comparing the percentages of 1) non-convulsions, 2) convulsions and recovery, and 3) convulsions with death, in the various populations. The method proved inapplicable because of the fact that some populations include too few members in some of the three classes. Also, evidence described below favors a hypothesis that death from convulsions does not merely result from a more severe convulsion or a greater seizure susceptibility. The strongest evidence in favor of a multiple gene hypothesis is the fact that three matings of non-convulsing F_2 animals yielded an F_3 which is practically identical in seizure risk to the $F_1 \times$C57bl group. This small sample (n=17) includes two subjects dying on the first trial, nine resisting five trials, one which recovered five times from severe convulsions, and five others which convulsed at least once. Certainly genes lowering resistance were well distributed in this group selected on the basis of successfully withstanding five exposures without convulsions. The results are most simply interpreted by a multiple factor hypothesis under which the number of susceptibility genes determines seizure risk. Animals in the F_2 having low genetic seizure risk may produce offspring with a high risk through segregation and recombination. Very large samples of F_2 and F_3 subjects must be available, however, to provide a critical test for the number of gene pairs involved, because of the fact that in low dilution there is at present no way to distinguish these genes. In fact, the detailed genetics must await a method of classifying

phenotypes which is based upon a quantitative unit of susceptibility, not a simple dichotomy into convulser or non-convulser.

THE PHYSIOLOGICAL GRADIENT OF SUSCEPTIBILITY

It has been shown above that there is no simple correspondence between genotype and phenotype in respect to audiogenic seizure incidence. This is well demonstrated in the genetically homogeneous F_1 which is extremely variable in seizure susceptibility. Furthermore, seizure susceptibility is not constant in one animal from day to day. One mouse may resist four exposures and die on the fifth, another may convulse and recover on the second exposure and be resistant on four other trials, while still another convulses and recovers five times. If one interprets the data from a statistical point of view, it must be concluded that the genotype actually determines the proportion of time during which an individual is susceptible. Mice of our dba subline 2 strain are almost always susceptible, the C57 blacks practically never susceptible, and the F_1's susceptible somewhere between 32 percent and 74 percent of the time. The extreme variability of the F_1's is, in fact, predictable on the basis of the hypothesis that what appears to be a character of alternative expression is in reality a quantitative character which varies over a wide range. The assay of this character by bell ringing merely divides the group into animals above and below a threshold at the moment of testing. Thus, the mode of inheritance appears to parallel that found by WRIGHT (1934) for polydactyly and WRIGHT and WAGNER (1935) for otocephaly in the guinea pig, and by HESTON (1942a and b) for lung cancer in mice. Audiogenic seizure susceptibility differs from these examples because no gross structural changes have been found, nor is any individual absolutely committed to a definite position on the scale. Susceptibility may shift up and down in an apparently random manner during the five day test period. However, this shifting apparently occurs within genetically prescribed limits which are the same for all members of the same genotype. In the repeat F_1 group the probability of not seizing on the first trial is 0.26 and of not seizing on any one of trials 2 to 5 is 0.85. The probability of not seizing on any trial is $0.26 \times 0.854 = 0.222$. The expected number of non-convulsers in 5 trials for the sample of 38 is 8.36, and the observed value, 8, is not significantly different.

If the non-genetic factors operate in a random manner, each genotype should include members grouped symetrically about a mean value of susceptibility. The curves of figure 1 express these relationships graphically. The abscissae represent differences of susceptibility in units of the standard deviation (t units), while the ordinates are arbitrarily drawn so that the area under each curve equals unity.

A genotype with a convulsive risk of 50 percent would have its midpoint at zero on the scale; genotypes with less resistance will have their midpoints in the negative region. At any moment in time a cross section of the genotype will yield seizure susceptible animals in proportion to the portion of the area under the curve lying to the left of the threshold. Individual animals, however, at different points in time shift their relationship to the threshold.

External conditions such as temperature, and the degree of restraint or mechanical agitation have been shown in preliminary experiments to affect seizure susceptibility. Such factors may be considered to move the population as a whole to the right or left along the susceptibility axis. Figure 1 demonstrates that changes of this sort influence the seizure risk of F_1 hybrids much more than the parent strains. The parents are assumed to be 6 t units apart and the F_1 to be exactly intermediate. The "normal" position of the F_1 in figure 1a is based upon the repeat F_1 sample. A convulsant agent is assumed in figure 1b to shift all curves to the left by one unit; and in figure 1c an anticonvulsant agent shifts them all one unit to the right. The parental values are arbitrarily selected, as the data to locate them exactly are not available. The

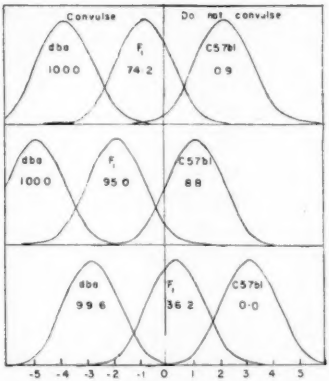

FIGURE 1. Changes in convulsive risk on first trial (figures under curves) associated with conditions shifting physiological susceptibility by one standard deviation. The abcissa is a scale of physiological susceptibility. Each genotype is assumed to vary normally about some point on this scale. The convulsive risk is dependent upon the proportion of the curve to the left of an arbitrary threshold. (a) The upper section represents the situation in the 'repeat' F_1; (b) the middle section approximates the results obtained by Witt and Hall; (c) the lower section approximates the results in the authors' 'original' F_1.

striking fact is that a change which greatly affects the hybrid is relatively unimportant to the parents. This accords with the observed agreement between investigators with respect to the susceptibility of the parent strains, and the variability between different samples of the hybrids.

The writers are unable to explain the discrepancy between their own "original" and "repeat" F_1 groups. The procedure for each was supposed to be the same, though the testing was done by a different person in a different room at a different time of year. Presumably some subtle environmental influence was responsible. Figures 1a and 1c approximately represent the two samples. Figure 1b approximates the WITT and HALL data which were obtained from a different subline of the dba strain.

COMPARISON OF CONVULSION RISK AND DEATH RISK

In the discussion of results thus far, only the incidence of convulsions has been considered. The hybrids, however, differ from the dba stock in another particular, the ability to recover from an induced seizure. Eighty-seven percent of convulsing dba's die on the first trial, and only one percent survive five trials. The dba backcross has nearly as high a convulsion risk as the dba, but only 62 percent of the first trial convulsers die, and 27 percent survive five trials. Data for the other hybrids are included in table 1.

The lowered death rate could be due to 1) less severe convulsions, 2) to an increased stress resistance in the hybrids, derived presumably from the C57 bl line, and 3) to a combination of these factors. The fact that the first trial death/convulsion ratio is so constant in the hybrids, although the incidence of seizures varies widely, is evidence in favor of a separate gene system influencing stress resistance. It is impossible to secure direct evidence on the ability of C57 blacks to recover from audiogenic seizures, since the incidence is so low. However, convulsions can be induced in C57 black mice by applying alternating current to the head. Electrogenic convulsions have many features in common with audiogenic convulsions, and in some strains of mice frequently result in death (STONE, EADY, and HANTY 1949). MR. A. J. COULOMBRE, working in the authors' laboratory, has determined the death/convulsion ratio in C57 bl mice at 30–40 days of age. Twelve mice given 7.5 milliamperes through electrodes applied to their ears convulsed, and five died. Although the sample is small, the rate of recovery from E.C.S. in C57 bl appears to be definitely higher than the rate of recovery of dba mice from audiogenic seizures, and is comparable to the rate of recovery in dba×C57 hybrids. Furthermore, observation indicates that animals may recover from long severe seizures, and die from seizures of apparently lesser intensity. Only mild forms of seizure involving hind limb paralysis without falling on the side never result in death.

Further evidence of independence of susceptibility and recovery has been obtained from a study of seizure latency. The interval between the onset of each convulsion and the beginning of the stimulus was recorded to the nearest second. The distribution of latencies is given in table 3. It is clear that the seizure latencies in the F_1 and $F_1 \times C57$ are significantly higher than in dba or $F_1 \times$dba. The two latter groups have a bimodal distribution of latencies,

TABLE 3

Distribution of seizure latencies for first three trials.

GROUP	LATENCY IN SECONDS										N	M
	0–9	10–19	20–29	30–39	40–49	50–59	60–69	70–79	80–89	90–99		
dba	1	20	3	32	43	9	—	—	—	—	108	35.8±1.2
$F_1 \times$dba	2	24	12	83	90	29	9	—	—	—	249	38.9±0.8
F_1	—	—	1	2	12	44	15	3	—	1	78	55.2±1.1
F_2	2	1	—	16	47	13	2	1	—	—	82	43.6±1.1
F_1xC57	—	—	—	2	18	14	8	4	2	—	48	54.5±1.7
Total	5	45	16	125	210	109	34	8	2	1	565	—

and there is a hint of bimodality in the F_2. The cause of this bimodality in the highly inbred parental strain presents an interesting problem for future experimentation. The data of table 3 are wholly consistent with the hypothesis that average seizure latency is an index of physiological susceptibility to audiogenic seizures. The distribution of the latencies is consistent with the hypothesis that the dba parent contributes genes reducing latency and the C57 parent contributes genes increasing latency. When these genes produce latencies of more than 80 seconds, convulsions seldom result. Hence the seizure latency of the C57 backcross is essentially the same as the F_1, although the seizure risk is much less.

Is seizure latency also related to death risk? An analysis of variance according to the genotype and outcome was carried out with the dba and F_1 hybrids. The results, summarized in table 4, show that only the difference between genotypes is significant, and there is no relationship between fatal or non-fatal outcome and latency. Convulsion risk and death risk once a convulsion is initiated depend upon different physiological mechanisms.

DISCUSSION

The findings reported here provide a basis for reconciling divergent results on the seizure susceptibility of dba and C57 bl hybrids. Although the con-

TABLE 4

*Analysis of variance of seizure latency according to genetic group and outcome of convulsions.**

	dba		F_1		W	D
	n_1	$\bar{x}_1$	n_2	$\bar{x}_2$		
Recover	27	34.4	59	54.7	18.52	20.3
Die	117	34.7	45	53.7	32.50	20.0

* In the analysis of variance calculated below $\bar{x}$ and D have been coded by dividing by 5. Correction for disproportion in the subclass numbers has been made according to SNEDECOR (1946, p. 284).

SOURCE OF VARIATION	d.f.	SUM OF SQUARES (UNCORRECTED)	CORRECTION FOR DISPROPORTION	MEAN SQUARE
Genetic	1	921.61	147.84	773.77
Outcome	1	156.43	147.84	8.59
Interaction	1			0.80
Individuals	246	1152.16		4.68

F (for genetic variance) = 773.77/4.68 = 165.33 (Significant at better than 1 %)
F (for outcome) = 8.59/4.68 = 1.83 (not significant)
F (for interaction) = 0.80/4.68 = 0.17 (not significant)

* Additional cases have been added to those reported in table 3 so that the numbers and means differ slightly. With respect to seizure latency the "original" and "repeat" F_1 samples are the same.

clusions presented here regarding the type of genic control of susceptibility differ from those of WITT and HALL, their data are perfectly consistent with the hypothesis presented. Subline differences may be expected to shift populations along the axis of physiological susceptibility, and the effect upon seizure risk will depend upon the particular region in which the shift occurs. Another probable cause of variation in results with hybrids, is the expected greater sensitivity of genotypes near the threshold to environmental influences. Evidence has been presented to show that such influences may be subtle, and hard to detect even when all ordinary precautions are taken.

The clear separation of seizure risk and death risk is of importance in considering the significance of experiments on the physiology of seizures. GINSBURG and co-workers (1947; in press) have reported several agents which protect against death without altering seizure incidence. It is almost certain that these operate on the recovery mechanism rather than on the physiological gradient of susceptibility postulated in this paper. Since the protective agents are related to modification of brain metabolism, it is probable that resistance to death from seizure depends upon the ability of the brain to sustain metabolism during the anoxia produced by the cessation of respiration at the climax of the convulsion.

The only clue to the nature of the physiological gradient of susceptibility is in the relationship of susceptibility and seizure latency. If one assumes that impulses entering the central nervous system over the auditory nerve cause the accumualtion of a substance or produce a polarized state, then differences in the rate of removal or destruction of the substance or leakage of electric charges would have an effect on the amount of time needed to reach a threshold. If the rate of destruction were sufficiently rapid the threshold would never be attained. Further speculation is of little value until experiments are designed to test this hypothesis.

SUMMARY AND CONCLUSIONS

1. A study of audiogenic seizure susceptibility has been made in hybrids between dba subline 2 and C57 bl subline 6.

2. Susceptibility to sound induced convulsions is probably due to multiple factors although the F_1 and F_1 backcross generations contain susceptible animals in proportions which approach those which would be expected on the basis of a single gene showing incomplete dominance.

3. The gene system producing susceptibility determines the position of an animal on a physiological gradient of susceptibility.

4. The ability to recover from a sound-induced seizure is also inherited, but is independent of seizure susceptibility.

5. The latency of seizure onset is related to convulsion risk, but not to death risk.

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ON MULTIPLE ALLELES EFFECTING CELLULAR ANTIGENS IN THE CHICKEN[1]

W. E. BRILES,[2] W. H. McGIBBON, AND M. R. IRWIN
University of Wisconsin, Madison, Wisconsin

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COINCIDENTALLY with the beginning of modern genetics in 1900, antigenic differences in the erythrocytes of members of two species of animals were discovered. LANDSTEINER (1900, 1901) made his now famous discovery of the blood groups of man. EHRLICH and MORGENROTH (1900) demonstrated the existence of individual differences in the antigenic constitution of goat erythrocytes. Later, TODD and WHITE (1910) proposed on the basis of their work with the cellular antigens of cattle that the red cells of almost every individual could be distinguished from those of any other individual.

LANDSTEINER and MILLER (1924) were the first to detect individual differences in the antigenic constitution of the erythrocytes of chickens. By absorbing rabbit anti-chicken serum individually with the cells of various chickens and testing the resulting fluids with the cells of ten individuals, eight different cell types were recognized. Following the injection of the blood of one chicken into another (iso-immunization), TODD (1930) found that iso-agglutinins were produced against the cells of the donor as well as against the cells of many other individuals. By using highly polyvalent antisera, produced by pooling the sera from several chickens which had been previously injected with the pooled cells of as many as 22 other chickens, TODD was able to show that the cells of any chicken, with the exception of close relatives, could be differentiated from the cells of every other individual. Further, he demonstrated that any cellular antigen possessed by an individual was present in the cells of one or both of its parents. Later TODD (1931) reported that the cells of each chick in each of three families appeared to have different absorptive or reactive capacities from the cells of every other chick, although some were quite similar. In accounting for the probably genetic relationships of the genes responsible for these observed antigenic differences, WIENER (1934) hypothesized the existence of three or more alleles at some loci.

KOZELKA (1933), using absorbed rabbit anti-chicken sera, found marked similarity in the corpuscles of individuals belonging to different breeds. This led him to believe that the apparent multiplicity of antigenic differences previously reported in chickens by TODD could be explained "by a variable assortment of a limited number of factors".

[1] From the Departments of Genetics (No. 411) and Poultry Husbandry, Agricultural Experiment Station, UNIVERSITY OF WISCONSIN. This project was supported in part by the Research Committee of the Graduate School from funds supplied by the WISCONSIN ALUMNI RESEARCH FOUNDATION.

[2] Present address, Department of Poultry Husbandry, A. AND M. COLLEGE OF TEXAS, College Station, Texas.

Normal cattle serum was found by LANDSTEINER and LEVINE (1932) to agglutinate differentially the cells of various chickens; also, antisera prepared against the Forssman antigen allowed a second independent classification of the cells of individual chickens. It was reported in the same paper that one of the authors, working with L. C. DUNN, had used rabbit anti-chicken serum to detect a single agglutinogen. Studies on several families had indicated that the antigenic character was controlled by a single dominant gene.

That agglutinogens may result from the action of recessive genes or from the complementary effect of non-allelic genes was suggested by the work of THOMSEN (1934, 1936) and BOYD and ALLEY (1940) in which agglutination of the red cells of a few individuals was obtained with a specific test-fluid even though the cells of both parents failed to react.

This paper describes the serological and genetic identification in chickens of cellular antigens, seemingly effected by two independent autosomal series of alleles.

MATERIALS AND METHODS

Most of the chickens used in these studies were Barred Plymouth Rocks, although New Hampshires and Single Comb White Leghorns were utilized to a limited extent. The Barred Plymouth Rocks will be indicated by number only; otherwise the breed or breed derivation will be given.

Iso-immune sera were prepared by injecting citrated whole chicken blood or washed red blood cells into closely related individuals. Approximately one cc of whole blood or 50 percent cell suspension was injected intravenously at three to four day intervals until the antibody titer was satisfactory—usually three to four injections were necessary, although occasionally excellent antisera resulted from a single injection. In the beginning of this study, the antisera were stored in a refrigerator (2 to 6°C) after merthiolate solution (1:100) had been added in sufficient quantity to give a final concentration of 1:2000. More recently the antisera have been stored in a deep freeze box (−18 to −32°C) without the addition of a preservative.

To prepare test-fluids or reagents specific for each antigenic factor, an antiserum was diluted with saline (according to its titer) and mixed with a suitable quantity of washed cells (usually 1 cc of cells to 1.6 cc of diluted antiserum). The mixture was allowed to stand at room temperature (22 to 26°C) with frequent agitation for 20 to 30 minutes, after which it was centrifuged. The resulting supernatant was mixed with a second portion of cells, and further absorption of the antibodies was allowed to take place for a period of one to two hours. Each subsequent absorption was similarly made except that one of the absorptions, usually the last, was placed in the refrigerator (2 to 6°C) overnight. The absorptions were repeated until the supernatant ceased to produce agglutination with the cells used in absorption. When not used immediately, the reagents were stored at −18 to −23°C.

The agglutination tests were performed by adding one drop of a two percent cell suspension in saline to two drops (0.1 cc) of a reagent in appropriate dilutions, usually made serially. Each mixture of cells and reagent was observed

for the presence of agglutination after standing for one and one-half hours at room temperature; confirmatory readings were made after storage of the test overnight in the refrigerator. Doubtful readings and negative controls were checked microscopically.

TERMINOLOGY

To facilitate the presentation of results, it seems advisable at this point to indicate the terminology used in designating the antigenic characters, their causative genes, and the test-fluids used in characterizing them. The antigens so far detected appear to be determined by genes belonging to one or the other of two series of alleles. The type of action displayed by the alleles of each series indicates a complete lack of dominance, so that each allele always produces its particular antigenic substance, regardless of the other alleles present. One series has been given the locus designation *A* and consists of nine alleles tentatively designated as follows: A^{123}, A^{1236}, A^{23}, A^{237}, A^{2346}, A^{23456}, A^{3456}, A^{8} and a. The letter a indicates an allele for which no antigenic effect has been detected with the reagents employed. Each digit in the superscript indicates the ability of the antigenic substance determined by that allele to react with the respective reagents designated by digits preceded by a standard capital letter indicating the locus of the gene producing the homologous antigen or antigenic factor. Thus, the reagents employed to designate the A series of antigens are A1, A2, A3, A5, A45, A456, A7 and A8. The reagents are simply test-fluids containing agglutinins whose specificities have been found to be limited to the antigenic component or components indicated by the digits following the capital letter. The antigenic unit determined by each allele is given a subscript designation in contrast to the superscript symbol assigned to the gene. The antigens produced by the above series of alleles are thus designated respectively as A_{123}, A_{1236}, A_{23}, A_{237}, A_{2346}, A_{23456}, A_{3456} and A_8.

A second series, given the locus designation *B*, consists of five alleles—B^{15}, B^{25}, B^{3}, B^{4} and b. The antigens produced by the *B* series of alleles are identified by means of the separate reagents B1, B15, B2, B3 and B4.

In general, an antigen is usually defined simply as any substance which, when introduced parenterally into an animal, stimulates the production of antibodies with which it will react. In discussing the results obtained in this study the term *antigen* will be used only in referring to the *total antigenic product* of an allele, while the term *antigenic factor* will be used in referring to the "serological components" of which the antigen appears to be composed. For example, the total antigenic product of the allele B^{15} is referred to as antigen B_{15}, which is composed of antigenic factors B_1 and B_5. These designations are made for the sake of convenience in discussion and should not be viewed necessarily as representing natural units.

PREPARATION OF REAGENTS

The various reagents resulted from the serological fractionation by selective absorption of the agglutinins present in iso-immune sera. As all of the reagents

were obtained in essentially the same manner, the preparation of reagents from only two antisera will be discussed as illustrative of the general method; however, the authors will supply on request the detailed procedure followed in obtaining any of the other reagents. The antisera to be used as examples do not necessarily correspond to the order of the discovery of the various antigenic factors.

The serological analysis of antiserum E962(E965), resulting from the injection of the blood of bird E965 into E962, is presented in table 1. The general procedure in carrying out an analysis of this kind was, first, to absorb the antiserum individually with the cells of birds selected at random or because of

TABLE 1

*Differential agglutination of test cells by test-fluids resulting from the absorption of antiserum E962(E965) with selected cells.**

TEST CELLS	PROPOSED ANTIGENIC FACTORS IN CELLS	ABSORBING CELLS								
		I989 (OR UNABSORBED)	I993	P143	P144	W29	W30	W33	W70	W29 AND I993
		AGGLUTININS REMAINING IN RESPECTIVE TEST-FLUIDS								
		A2, A4	A2	None	None	A4	A4	A4	A4	None
2712	A_2, A_4	++	+	0	0	++	++	++	++	0
I977	None	0	0	0	0	0	0	0	0	0
I988	None	0	0	0	0	0	0	0	0	0
I989	None	0	0	0	0	0	0	0	0	0
I992	A_4	++	0	0	0	++	++	++	++	0
I993	A_4	++	0	0	0	++	++	++	++	0
P72	None	0	0	0	0	0	0	0	0	0
P107	None	0	0	0	0	0	0	0	0	0
P142	None	0	0	0	0	0	0	0	0	0
P143	A_2, A_4	++	+	0	0	++	++	++	++	0
P144	A_2, A_4	++	+	0	0	++	++	++	++	0
P178	None	0	0	0	0	0	0	0	0	0
P179	None	0	0	0	0	0	0	0	0	0
W28	A_2	++	++	0	0	0	0	0	0	0
W29	A_2	++	++	0	0	0	0	0	0	0
W30	A_2	++	++	0	0	0	0	0	0	0
W31	A_2	++	++	0	0	0	0	0	0	0
W32	A_2	++	++	0	0	0	0	0	0	0
W33	A_2	++	++	0	0	0	0	0	0	0
W61	A_2, A_4	++	++	0	0	++	++	++	++	0
W62	A_2	++	++	0	0	0	0	0	0	0
W70	A_2	++	++	0	0	0	0	0	0	0

* The serum was diluted 1:2 for the absorptions; the test-fluids were diluted again 1:2 for the agglutination tests, except for the absorption controls, where no dilution was made.

Symbols: ++=strong agglutination, +=definite agglutination observable macroscopically, 0=no agglutination.

their antigenic constitution and, second, to test the absorbed fluids with the cells of selected individuals. After the agglutination results were obtained following the exploratory single absorptions, it was frequently necessary to make absorptions with the pooled cells from two or more individuals in order to complete the analysis.

It may be seen in table 1 that there were four kinds of cells among those tested for agglutination. The first type of cell (I977, I988, I989 and others as listed in the first column) failed to react with the unabsorbed antiserum or with any of the absorbed fluids prepared from this antiserum.

When cells from this non-reactive group (that is, I989) were used in absorbing this antiserum, agglutinins remained for the cells of various individuals, which subsequently could be divided into three groups. The cells of the second group (W29, W30, W33, W70 and others) reacted with the test-fluid prepared by absorbing this antiserum with the cells of I993. To account for the reaction of these cells with this test-fluid it was necessary to postulate at least one antigenic factor for the cells and a corresponding agglutinin for the fluid, which were given the symbols A_2 and A2, respectively.

When the cells possessing the A_2 factor (W29, W30, W33 and W70) were used in absorbing the anti-serum, agglutinins were left for the third and fourth classes of reactive cells. The reaction of one of these classes of cells (I992 and I993) requires an antigenic factor different from A_2, and a corresponding agglutinin for the test-fluids; this second antigenic factor and its homologous antibody were given the symbols A_4 and A4 respectively. The fourth class of cells (2712, P143, P144 and W61) reacted with both the A2 and A4 test-fluids. Further, when the cells of two of these, P143 and P144, were used separately in absorbing the antiserum, the agglutinins were removed for all of the test cells (table 1). Therefore, it is reasonable to conclude that the cells of these two birds possessed the two antigenic factors A_2 and A_4 *in toto*. Because of the similarity of the reactions of the cells of these two individuals and those of 2712 and W61, it is reasonable to assume that the cells of the latter two birds also possessed the A_2 and A_4 factors. Evidence that the antiserum did not contain more agglutinins reactive with the test cells than those represented by the A2 and A4 antibody fractions is afforded by the ability of pooled A_2 (W29) and A_4 (I993) cells to exhaust this antiserum of antibodies (table 1).

The A2 reagent used in detecting the A_2 antigenic factor referred to in subsequent sections of this paper was prepared by absorbing antiserum E962 (E965) with the cells of bird I993. Because of its special value as a source of A2 reagent, this antiserum was not utilized subsequently as a source of A4 reagent.

Additional immunizations were made to obtain a second source of A4 reagent using as donors birds whose cells possessed the A_4 antigenic factor and as recipients, birds whose cells lacked it. One antiserum—resulting from the injection of the blood of male R439, with factors A_1, A_2, A_3 and A_4, into male R428, with factors A_2 and A_3—contained A4 antibodies in relatively high concentration. The antigenic factors A_1 and A_3, involved in this immunization, were detected by reagents prepared in essentially the same manner as the A2

reagent just considered. When this antiserum, R428(R439), was absorbed with selected cells, a fluid was produced which reacted only with the cells of those individuals previously shown to possess the A_4 antigenic factor.

Since this absorbed fluid appeared to contain only antibodies reactive with the A_4 antigenic factor, it was designated as an A4 reagent. However, as a result of employing this reagent in testing the cells of the progeny from appropriate matings, it was later shown that this A4 reagent contained at least three fractions of antibody—A4, A5 and A6. The procedure used in detecting serologically these antibody fractions and in identifying simultaneously the genetic relationships of the homologous antigenic factors follows. Birds possessing both the A_1 and A_4 factors were mated to individuals possessing neither of them. The birds involved in these matings were Barred Plymouth Rocks, except for one New Hampshire male, 2738, whose cells were reactive with both the A1 and A4 reagents. The progeny of the Barred Plymouth Rocks showed a 1:1 segregation of the genes determining the A_1 and A_4 antigens, suggesting that the two antigens were determined by allelic genes. However, the cells of all the progeny resulting from the New Hampshire male reacted with the A4 reagent, while the cells of only half of his progeny reacted with the A1 reagent. This difference in segregation indicated that the genes or gene combinations effecting the A_1 and A_4 antigenic factors in this male (2738) and in the Barred Plymouth Rocks were different. It was noticed that the cells of the A_1 progeny of male 2738 reacted more weakly with the A4 reagent than did the cells of the non-A_1 segregates. This suggested that this male possessed two allelic genes each of which produced similar but not identical antigens; that is, while the two antigens produced by the *A* alleles contributed by this male were agglutinable to a different degree by the A4 reagent, only the antigen least reactive with A4 possessed the ability to react with the A1 reagent. To test this possibility, A_1 and A_4 progeny from the Barred Plymouth Rock matings and the two kinds of segregates from the New Hampshire male were used individually in absorbing antiserum R428(R439). As can be seen from examining table 2 it was necessary to postulate two additional antigenic factors, A_5 and A_6, to explain the reactions obtained in the analysis of this antiserum.

In interpreting the data obtained from the differential absorption of a complex antiserum, as shown in table 2, it is advisable to group together cells showing the same reaction pattern and to consider the cell-groups in the order of their reactivity; that is, the group or cell-type showing agglutination with the smallest number of absorbed fluids (or with none of them) is considered first, followed by the consideration of the next most reactive cell-type, etc. The cell-type to be considered first in table 2 is R2094, representing the A_1 segregates from the Barred Plymouth Rock matings; this type of cell did not react with any of the absorbed fluids. The second cell-type in order of reactivity is represented by those of chicks R2100 and R2102—the A_1 segregates from New Hampshire male 2738. Cells of this type were agglutinated only by the absorbed fluid indicated by code number 6. Since the cells of bird R2094 used in absorbing fluid 6 contained A_1, any antibodies remaining must have reacted with an additional antigenic factor, arbitrarily assigned the symbol A_6.

The third cell-type in order of reactivity is represented by R2071 and R2076—the non-A_1 segregates from the New Hampshire male. To explain the reactions of this type of cell with fluids 7 and 8 it was necessary to hypothesize an additional antigenic factor; since this factor segregated with respect to A_1 in the progeny of male 2738, it was given the symbol A_4 in accordance with the behavior of the A_1 and A_4 factors present in the Barred Plymouth Rocks. The most reactive cell-type is represented by birds R2090, R2092, R2093 and R2117—the non-A_1 segregates from the Barred Plymouth Rock matings. To

TABLE 2

*Differential agglutination of test cells by test-fluids resulting from the absorption of antiserum R428(R439) with selected cells.**

TEST CELLS	PROPOSED ANTIGENIC FACTORS IN TEST CELLS	ABSORBING CELLS								
		R2071†	R2076†	R2090	R2092	R2093	R2094	R2100†	R2102†	R2117
		AGGLUTININS REMAINING IN RESPECTIVE TEST-FLUIDS								
		A5	A5	NONE	NONE	NONE	A4,A5,A6	A4,A5	A4,A5	NONE
R2071†	A_4, A_5	0	0	0	0	0	++	+	+	0
R2076†	A_4, A_5	0	0	0	0	0	++	+	+	0
R2090	A_4, A_5, A_6	++	++	0	0	0	++	++	++	0
R2092	A_4, A_5, A_6	++	++	0	0	0	++	++	++	0
R2093	A_4, A_5, A_6	++	++	0	0	0	++	++	++	0
R2094	A_1	0	0	0	0	0	0	0	0	0
R2100†	A_1, A_6	0	0	0	0	0	++	0	0	0
R2102†	A_1, A_5	0	0	0	0	0	++	0	0	0
R2117	A_4, A_5, A_6	++	++	0	0	0	++	++	++	0
Code number of test-fluids		1	2	3	4	5	6	7	8	9

* The serum was diluted 1:8 for the absorptions; test-fluids were used undiluted.

† These birds resulted from the mating of New Hampshire male 2738 with Barred Plymouth Rock hens; the remainder of the birds were Barred Plymouth Rocks.

For explanation of symbols, see table 1.

account for the reactions of this type of cell with fluids 1 and 2 a third antigenic factor, A_5, was hypothesized. Thus, a minimum of three antigenic factors was necessary to explain adequately the agglutination reactions obtained after this antiserum was individually absorbed with four serologically distinct cell-types.

To determine the combinations of antigenic factors comprising the different cell-types, it was necessary to ascertain what antibody fractions remained in the antiserum after absorption by each of the cell-types. At this point it is preferable to consider first the simplest or least reactive test-fluid just as above the least reactive cell-type was considered first. Test-fluids designated in the table as code numbers 3, 4, 5 and 9 contained no antibodies; this means that the cells used to absorb the antiserum in producing these fluids contained all three of the antigenic factors—A_4, A_5 and A_6—for which the antiserum contained specific antibody fractions. The simplest type of test-fluid having antibodies remaining after absorption is represented by code numbers 1 and 2. The agglutination reactions produced by these fluids were previously accounted for

by antigenic factor A_5; therefore, the antibody fraction remaining in this fluid was designated A5. In order for the A5 antibody fraction to have remained after absorption, the cells of R2071 and R2076 must have removed antibody fractions A4 and A6; therefore, the cells of these two birds were assigned antigenic factors A_4 and A_6. The third type of test-fluid in order of reactivity is represented by code numbers 7 and 8. These fluids contained antibody fractions A4 and A5 since the cells used in absorbing the antiserum to prepare these fluids had been previously shown to possess only the antigenic factor A_6. Finally, the absorbed fluid producing agglutination with the greatest number of cell-types is that designated by code number 6. Since the cells of bird R2094, used in absorbing this fluid did not react with any of the test-fluids, it would not be expected to remove any one of the three antibody fractions—A4, A5 or A6—from the antiserum. This result was actually obtained when the cells of this bird were used in absorption; that is, when the resulting fluid was subjected to further individual absorptions with the three reactive cell-types, the presence of the three antibody fractions could be demonstrated (in the same manner as for the original antiserum in table 2).

Apart from their association with other antigenic factors, A_4, A_5 and A_6 have been found to exist only in certain combinations; namely, A_6, A_4A_6 and $A_4A_5A_6$ (table 2), henceforth designated as antigens A_6, A_{46} and A_{456}. By absorbing antiserum (R428(R439) with the cell-types possessing known antigenic combinations it was possible to prepare only three reagents—A5, A45 and A456. Reagents specific for the A_4 or A_6 antigenic factors could not be prepared from antiserum R428(R439) because the cell-types or combinations of types, A_5A_6 and A_4A_5, with which absorption would be necessary for the preparation of such reagents, have not been found.

The remainder of the reagents used in testing the cells of the progeny from the matings to be presented subsequently were all prepared in a manner essentially the same as that discussed above, and the presentation of the details of their preparation does not seem warranted in this report.

GENETIC RESULTS

The Genetic Relations of the Genes Effecting the A Group of Antigens

Initially, when the work involved primarily serological techniques, each reagent was designated by a different letter of the alphabet, on the assumption that the various reagents were reacting with independently inherited antigens. However, as soon as data on genetic segregation were obtained, it was found that the antigens with which the reagents reacted were frequently associated in complexes; that is, the ability of the cells of the progeny from certain matings to react with one reagent was perfectly correlated with their ability to react with a second reagent. For example, when male 2758, whose cells reacted with both the A2 and A3 reagents, was mated with hens W30, W31, W32, W65 and W68, whose cells likewise reacted with the A2 and A3 reagents, two kinds of progeny resulted—35 individuals whose cells reacted with both of the reagents and 13 individuals whose cells failed to react with either of the reagents.

Each dam produced at least one chick whose cells were non-reactive. The mating of these hens with this male constitutes mating 1 of table 3. A single pair of allelic characters and therefore, a single pair of genes is sufficient to account for this simple 3:1 ratio. These proposed alleles were given the locus designation *A*, and the two reagents were thereafter designated A with numbers following the letter to distinguish them—A2 and A3 being used as symbols to represent these two serologically distinct reagents. The allele having the

TABLE 3

The distribution of the progeny resulting from parents selected on the basis of the reaction of their cells with the A reagents.

MATING	PROPOSED GENOTYPE OF PARENTS	ANTIGENS POSSESSED BY THE PROGENY							
		a	A_{23}	A_{123}	A_{1236}	A_{2346}	A_{23456}	A_{237}	A_8
1	$A^{23}/a \times A^{23}/a$	13	35	—	—	—	—	—	—
2	$A^{234(56)*}/a \times a/a$	4	—	—	—	—	6	—	—
3	$A^{23456}/a \times a/a$	11	—	—	—	—	9	—	—
4	$A^{(23)456}/a \times A^{(23)}/A^{(23)}$ or $A^{(23)}/a$	87	—	—	—	—	84	—	—
5	$A^{1(2)3}/A^{(2)3466} \times A^{(2)3}/A^{(2)3}$ or $A^{(2)3}/a$	—	—	26	—	—	25	—	—
6	$A^{123}/A^{23} \times a/a$	—	2	4	—	—	—	—	—
7	$A^{1(2)36}/A^{(2)346} \times A^{(2)3}/a$ or $A^{(2)3}/A^{(2)3}$	—	—	—	37	48	—	—	—
8	$A^{(23)456}/A^{(23)7} \times A^{(23)}/A^{(23)}$	—	—	—	—	—	43	46	—
9	$A^{(23)4.6}/A^{8} \times A^{(237)}/A^{(23)}$	—	—	—	—	—	11	—	10

* When a digit of the superscript is enclosed in parenthesis, it indicates that the reagent detecting that particular antigenic component in the parent was not used in testing the cells of the progeny.

recognizable antigenic effect was given a numerical superscript indicating the reagents with which its antigenic product reacted; for example, since the cells of male 2758 and each of the hens W30, W31, W32, W65, and W68, reacted with the reagents A2 and A3, they were assigned the genotype A^{23}/a, *a* being the designation for any gene or genes at the *A* locus for which no antigenic effect had been recognized.

During this same early stage of the work, evidence was obtained that the ability of cells to react simultaneously with the A2, A3 and A4 reagents was probably also determined by a single gene, or at least by a chromosome unit failing to fractionate at segregation. This evidence consisted of the agglutination reactions obtained with ten progeny resulting from the mating of male 2712 (whose cells reacted with reagents A2, A3 and A4) with females P178 and P179 (the cells of neither of which were reactive with any of the three reagents). Mating 2 of table 3 represents the data obtained from these two matings. Among the ten progeny only two types were obtained; six whose cells reacted with all three of the A reagents (A2, A3 and A4) and four whose cells were not agglutinated by any of them. Thus, tentatively at least, it seemed plausible to assign all three reactions to the product of a single gene; this gene was designated A^{234}. Further work disclosed the ability of the pre-

sumed antigenic product of this gene, A^{234}, to react with the two other fractions of antibody, A5 and A6. From the same type of mating as that just considered, male R426 (A^{23456}/a) mated to female P827(a/a) (mating 3 of table 6), there resulted 20 progeny, which, when tested with reagents A2, A3, A5, A45, and A456, fell into two distinct classes—nine individuals whose cells reacted with all five reagents and 11 whose cells did not react with any of them. The 11 negative individuals are of special importance since they represent gametes resulting from simultaneous segregation toward one pole during the reduction division of genic material having to do with the production of the five antigenic components. If any breakdown had occurred in the apparently constant association of the five antigenic components, individuals would be expected whose cells were capable of agglutination with only a portion of the five reagents employed. The nine individuals of the "positive" class resulting from this mating showed definitely that the A_2, A_3 and A_5 factors segregated together, but whether or not the factors A_4 and A_6 were also present could not be determined, due to the fact that the reagents A45 and A456, available for the detection of these factors, also contained antibody for the A_5 factor. For example, if the antigenic complex A_{235} had appeared in the cells of certain progeny, it would have reacted with reagents A45 and A456 by virtue of the A_5 antigenic component. However, any of the progeny whose cells contained factors A_4, A_6 or A_{46} in the absence of A_5 would have been readily identified as antigenic variants by the reagents employed in testing the progeny.

Additional progeny from the mating of heterozygotes (A^{23456}/a) with homozygotes (a/a) were not obtained, seemingly due to the low fecundity of the homozygous type. However, numerous individuals carrying the A^{23} allele, usually in the heterozygous condition, were available for use in matings with individuals of the A^{23456}/a genotype. Mating 4 of table 3 gives the data obtained from testing the progeny resulting from the mating of male R426 (A^{23456}/a) to hens whose cells reacted only with the A2 and A3 reagents. Three of these hens carried the A^{23} allele in heterozygous condition (A^{23}/a) while two appeared to be homozygous for A^{23}. The cells of all of the progeny were tested with reagents A5, A45 and A456, but they were not tested with reagents A2 or A3 (in table 3 any antigenic factor possessed by a parent and not tested for in the progeny is enclosed by parenthesis in the proposed genotype of the parent). As a result of testing their red cells for agglutination, the progeny fell into two classes—87 non-reactors and 84 whose cells reacted with all three reagents. As pointed out above, in direct agglutination tests employing the available reagents the antigenic factors A_4 and A_6 could not be detected in the presence of the A_5 factor; therefore, in order to determine the extent to which the "positive" segregates of mating 4 received all three of the components (A_4, A_5 and A_6), the cells of 26 of these segregates, chosen at random, were used individually to absorb the A456 reagent. In every instance the cells of each of the 26 positively reacting segregates removed the three antibody fractions, as evidenced by the failure of the absorbed fluids to agglutinate the cells of male R439, against which these antibody fractions were originally produced in immunization. Therefore, the cells of at least 26 of the 84 positively reacting

segregates contained *in toto* the antigenic factors A_4, A_5 and A_6.

In mating 5 ($A^{123}/A^{23456} \times A^{23}/A^{23}$ or A^{23}/a) of table 3 the allele A^{123} is introduced. The cells of the 51 progeny resulting from this mating were tested with reagents A1, A3, A5, A45 and A456. (The reagent A2 was not available in sufficient quantity to allow its use in testing these birds.) Here again, although tested with five serologically different reagents, the progeny fell into only two groups; 26 of them reacting with reagents A1 and A3 and 25 reacting with reagents A3, A5, A45 and A456. Of the 25 individuals belonging to the latter class, 17 were used in absorbing the A456 reagent in the same manner as was done with a portion of the positively reacting progeny from mating 4. Here, also, no antibodies remained after absorption, showing that the blood of each individual used in absorption possessed the entire A_{456} complex. The data from matings 4 and 5 indicate strongly that the genic material responsible for the appearance of the A_{456} antigenic complex is unitary—presumably a single gene.

Further serological characterization of the antigenic substance produced by the allele responsible for the A_1 factor is afforded by the agglutination reactions obtained with the cells of the progeny resulting from mating 6 ($A^{123}/A^{23} \times a/a$). The ability of the four chicks receiving the A_1 factor, presumably of the genotype A^{123}/a, to react also with the A2 and A3 reagents indicates that the antigen produced by this allele also possessed the capacity to react with the A2 and A3 reagents. Additional evidence for the multiple serological properties of the substance produced by the A^{123} allele is afforded by hen P720, whose cells were agglutinable by reagents A1, A2 and A3 and who was proven to have the genotype A^{123}/a. When mated to male 2776 (A^{23456}/A^{23}), this hen produced among her progeny three females R407 (A^{23}/a), R408 (A^{23456}/a) and R411 (A^{23456}/a). Each of these three birds was shown to carry the *a* allele by virtue of the a/a progeny which resulted when they were mated to male R426(A^{23456}/a). In view of these findings it seems reasonably certain that the allele A^{123} produces an antigen capable of reacting with the reagents A1, A2 and A3.

Two additional antigenic complexes probably effected by genes at the *A* locus were derived from New Hampshire male 2738. As given in mating 7 of table 3, the probable genotype of this male was A^{1236}/A^{2346}. This male was placed in a mating pen with ten females, five of which were known as a result of a previous progeny test to possess the genotype A^{23}/a; the remaining five hens could have had either genotype A^{23}/a or A^{23}/A^{23}, although none of them were proven to be of the latter type. The ten dams were either sibs or half sibs, and since all those adequately progeny-tested had been proven to be heterozygous, it is likely that most, if not all, of those with indefinite genotypes were also of the A^{23}/a type. The progeny from this mating were tested with reagents A1, A3, A45 and A456. Since at least half of the dams were transmitting the *a* allele, it is not likely that the universal presence of the A_3 factor in the cells of the 85 progeny could be accounted for by the A^{23} allele derived only from the dams; it is highly probable that both alleles transmitted by male 2738 were capable of producing the A_3 factor. Rather conclusive evidence that

both of the alleles carried by the male 2738 produced antigens capable of reacting with the A2 and A3 reagents consists of data collected on four chicks before the A_5 and A_6 factors had been recognized. These chicks resulted from the mating of male 2738 (A^{1236}/A^{2346}) with a hen of the genotype a/a. All four of the chicks reacted with both the A2 and A3 reagents; the cells of two of the chicks were positive with the A4 reagent while those of the other two were positive with the A1 reagent. These results can most satisfactorily be accounted for by assuming that the genotypes of the chicks were either $A^{123(6)}/a$ or $A^{234(6)}/a$; as shown above these appear to constitute the two segregating genotypes found among the progeny of male 2738.

Due to the serological similarity of the antigens produced by the alleles A^{1236} and A^{2346} with the antigens produced by the A alleles, it is highly probable that they also occupy the A locus, but because of the lack of matings between birds of appropriate genotypes genetic proof of the allelic relationship has not been obtained.

The most recently identified alleles of the A series are A^{237} and A^8. From mating 8 ($A^{23456}/A^{237} \times A^{23}/A^{23}$) there resulted 43 progeny whose cells were reactive with the A456 reagent and 46 progeny whose cells were reactive with the A7 reagent, indicating that the genes responsible for the presence of these two serologically distinct substances were segregating in a manner characteristic of alleles. Likewise, in observing the antigenic constitution of the 21 progeny from mating 9 ($A^{23456}/A^8 \times A^{237}/A^{23}$) it is evident that the 11 progeny positive with the A456 reagent and the 10 progeny positive with the A8 reagent indicate an allelic relationship of the causative genes. That the antigenic substance reactive with the A7 reagent is also capable of reacting with the A2 and A3 reagents is indicated by the positive reactions of these reagents with the cells of three individuals of the genotype A^{237}/A^8 resulting from mating 9. Since the reagent detecting the presence of antigen A_8 was not available until recently, the gene responsible for the production of this antigen previously constituted one of the alleles designated by the symbol a, given to any A allele for which no antigenic effect has been detected.

The antigenic combination A_{3456} has been found in only two sisters, I992 and I993, neither or which produced progeny; genetic proof, therefore, that this antigenic combination is due to a gene of the A locus is lacking. However, in view of the particular absorptive capacity and cross reactivity of this antigen with the A reagents, it is clear that these two birds possessed an A allele different from those present in the cells of the other birds utilized in these studies.

Genetic proof that the antigenic complex A_{23} is produced by an A allele is also lacking at the present time, largely due to the difficulty of setting up appropriate matings for testing allelism when the antigenic factors A_2 and A_3 occur in most of the antigens produced by this series of alleles. With the recent discovery of the allele A^8 it is likely that the desired segregation data can be obtained. However, the serological similarity of the A_{23} antigenic substance with those produced by the other members of the A locus indicates strongly that its causative gene is a member of the A series of alleles.

The Genetic Relations of the Genes Effecting the B Antigens

A second series of antigens, effected by genes occupying a locus different from that of the *A* alleles, has been tentatively designated by the symbols B_{15}, B_{25}, B_3 and B_4. Evidence indicating the allelic nature of the genes effecting these antigens is presented in table 4. In each mating listed in the table the cells of one of the parents gave positive reactions with each of two B reagents, that is, one parent carried genes effecting two B antigens; while the other parent of each mating, represented by the genotype *b/b*, was negative with the

TABLE 4

The distribution of the progeny resulting from parents selected on the basis of the reaction of their cells with the B reagents.

MATING	PROPOSED GENOTYPE OF PARENTS	ANTIGENS POSSESSED BY THE PROGENY				
		b	B_{15}	B_{25}	B_3	B_4
1	$B^{1(5)*}/B^{2(5)} \times b/b$	—	41	40	—	—
2	$B^{1(5)}/B^3 \times b/b$	—	118	—	111	—
3	$B^{2(5)}/B^3 \times b/b$	—	—	73	97	—
4	$B^{2(5)}/B^4 \times b/b$	1(?)	—	16	—	24
5	$B^3/B^4 \times b/b$	—	—	—	26	24
6	$B^{25}/B^3 \times b/b$	—	—	14	10	—

* When a digit of the superscript is enclosed in parenthesis, it indicates that the reagent detecting that particular antigenic component was not used in testing the cells of the progeny.

(?) The parentage of this chick was doubtful; for explanation, see text.

same two reagents. Neglecting for the present the doubtful exception to be considered later, it may be seen that from each mating listed in table 4 there resulted only progeny possessing one or the other of the two antigens characterizing the first parent. For example, when the cells of the progeny of mating 1 ($B^{15}/B^{25} \times b/b$) were tested with reagents B1 and B2, 41 offspring were reactive with the B1 reagent and 40 were reactive with the B2 reagent. The appearance of the two contrasting classes among the progeny indicates that the genes controlling the ability of the cells to react with the reagents were segregating in a manner characteristic of alleles. Likewise the progeny resulting from mating 2 ($B^{15}/B^3 \times b/b$) fell into two classes when tested with the B1 and B3 reagents. Of the 229 offspring from this mating, 118 possessed the antigen B_{15} and 111 possessed the antigen B_3—again indicating an allelic relationship of the causative genes. From these allelic relationships of B^{15} with both B^{25} and B^3, it can be concluded that B^{25} and B^3 are allelic. The classes of offspring resulting from mating 3 ($B^{25}/B^3 \times b/b$)—73 progeny reactive with the B2 reagent and 97 reactive with the B3 reagent—support the above proposal that the genes effecting antigens B_{25} and B_3 belong to the same allelic series. In the same manner the classes of progeny resulting from matings 4 ($B^{25}/B^4 \times b/b$) and 5 ($B^3/B^4 \times b/b$) indicate that the gene producing the B_4 antigen also belongs to the *B* series of alleles.

Among the progeny resulting from mating 4 of table 4, there was one bird which failed to react, even after repeated testing, with either the B2 or B4 reagents. If it could be proved that this individual actually resulted from the mating to which it was assigned, the validity of the hypothesis regarding the allelic relationship of the genes producing the B antigens would be doubtful. Hen R409, the supposed dam of this chick, was the only hen of genotype B^{25}/B^4 in a pen mating of seven birds. By assigning an egg of any other hen to R409 the discrepant chick could be accounted for. Furthermore, if the chick had hatched from an egg laid by R409, it would have had a probability of 0.5 of receiving the A^{123} allele from the dam since she was heterozygous for this allele; however, when tested with the A1 reagent, the cells of this chick were not reactive. Had this chick possessed the antigen A_{123}, thus confirming that R409 was the dam, it would have constituted serious evidence against the proposed allelic relationship of the genes producing the antigens B_{25} and B_4.

Until recently, largely due to the manner in which the B reagents were prepared, each allele of the B series of antigens appeared to produce only one antigenic factor. This apparent simplicity probably resulted from the particular combinations of birds used in producing and absorbing the antisera. For example, in preparing the B4 reagent, cells containing antigen B_4 were injected into an individual possessing antigen B_3; this meant that no antibodies could be produced against any antigenic factor common to both the B_3 and B_4 antigens, since a recipient can not produce antibodies reactive with antigens present in its own cells. Further, in the preparation of the B4 reagent from the above antiserum, any antibodies engendered against B_4 which were also cross-reactive with the B_1 and B_2 antigenic factors were removed by absorption with the cells of a bird of the genotype B^1/B^2. As a result, any antibodies present in the B4 reagent were highly specific for the antigen determined by the B^4 allele.

The only component thus far shared between antigens produced by alleles of the *B* locus is the B_5 factor which is common to B_{15} and B_{25}. This common component or factor was detected with antibodies produced as a result of the injection of cells containing the antigen originally termed B_1 into a bird possessing the antigen B_3. When this antiserum was absorbed with the cells of certain individuals, antibodies remained which were reactive with cells containing both antigens B_1 and B_2, as they were then designated. When the cells from an individual possessing the homologous antigen B_1 were used in absorbing this fluid, no antibodies remained. However, when this fluid, reactive with both the B_1 and B_2 antigens, was absorbed with cells possessing the B_2 antigen, there remained only antibodies for the B_1 antigen. Thus, the reagent B15 contained an antibody fraction, designated as B5, which was reactive with both antigens B_1 and B_2 as well as a fraction specific for the antigen B_1. To indicate the common antigenic component, the symbols for the antigens B_1 and B_2 were changed to B_{15} and B_{25} respectively.

Birds of the same genotype as proposed for mating 3 were used in mating 6 ($B^{25}/B^3 \times b/b$), but they are listed separately in table 4 because the progeny were tested with the B15 reagent in addition to the B2 and B3 reagents. When tested with the three reagents, the progeny from mating 6 were found to con-

sist of 14 birds whose cells were reactive with both the B15 and B2 reagents and 10 birds whose cells were reactive with only the B3 reagent. This is tentative evidence that the B_2 and B_5 antigenic factors are produced by a single gene. Further investigation may reveal other antigenic factors common to the antigens determined by the various *B* alleles.

The Genetic Relationships of the A and B Loci

The chromosomal relationship between the *A* and *B* loci is indicated by the data presented in table 5. This table shows the distribution of the classes of progeny resulting from the mating of male R426 of the genotype A^{23456}/a B^{15}/B^{3} with females which can be represented by the genotype a/a b/b, since the dams were negative with the reagents A5, A45, A456, B1 and B3 with which the progeny were tested. That is, even though the dams carried the allele A^{23}, they can be represented as a/a for the sake of convenience since the

TABLE 5

*The progeny resulting from the mating of male R426 of genotype A^{23456}/a B^{15}/B^{3} with females of genotype a/a b/b.**

AGGLUTINATION OF CELLS OF PROGENY WITH REAGENTS:					NUMBER IN EACH CLASS	PROPOSED GENOTYPES
A5	A45	A456	B1	B3		
+	+	+	+	0	45	A^{23456}/a B^{15}/b
+	+	+	0	+	43	A^{23456}/a B^{3}/b
0	0	0	+	0	49	a/a B^{15}/b
0	0	0	0	+	48	a/a B^{3}/b

* The genotype a/a b/b indicates that the cells of the dams did not react with any of the reagents (A5, A45, A456, B1 and B3) used in testing the progeny. The actual dams and their genotypes were R407 and R408 (A^{23}/a B^{4}/b), R443 and R450 (A^{23}/A^{23} b/b), and W65 (A^{23}/a b/b).

The symbols (+) and (0) indicate the presence and absence of agglutination, respectively.

progeny were not tested with the reagents A2 or A3. Also, two of the hens actually carried a third *B* allele, B^{4}, for which the progeny were not tested.

The 185 progeny from the above mating fell into four equally frequent classes, presumably of the following genotypes: A^{23456}/a B^{15}/b, A^{23456}/a B^{3}/b, a/a B^{15}/b, and a/a B^{3}/b (table 5). These data indicate that the genes at the *A* and *B* loci segregated independently. This means that the loci are on different chromosomes or that the two loci are separated on the same chromosome by 50 or more cross-over units. Because of the large number of chromosomes (40 pairs, reported by MILLER, 1938) and the small size of most of them, the possibility of loose linkage is relatively remote, and until both of these loci can be shown to be linked to a third locus, it may be assumed that they are located on different chromosomes.

Table 6 gives the reactions obtained with the cells of individuals possessing representative genotypes, which in each instance were determined by progeny test. However, by considering the pedigree in conjunction with the agglutina-

tion tests on the cells of the progeny, it was frequently possible to establish the presumed genotype of the offspring without resorting to the progeny test. For example, the genotypes of the progeny from the mating of male 2776 (A^{23456}/A^{23} B^3/B^4) with female P827 (a/a B^{15}/B^{25}) could be determined by simply testing their cells with the appropriate reagents (A2, A3, A456, B1, B2, B3 and B4). At the A locus the offspring would be either A^{23456}/a or A^{23}/a, and at the B locus they would be heterozygous for alleles effecting independently recognizable antigens—B^{15}/B^3, B^{15}/B^4, B^{25}/B^3, or B^{25}/B^4. Thus, by making appropriate matings it was possible to determine directly the genotype of the progeny by testing their red cells with suitable serological reagents.

The A and B loci are autosomal; this was shown by the ability of either

TABLE 6

The reactions obtained when the cells from birds of various genotypes were tested with the A and B reagents.

BIRDS	PROPOSED GENOTYPE	AGGLUTINATION OF CELLS WITH REAGENTS:										
		A1	A2	A3	A5	A45	A456	B1	B2	B3	B4	B15
2712*	A^{23456}/a B^{15}/B^{25}	0	+	+	+	+	+	+	+	0	0	+
2738*	A^{1256}/A^{2346} b/b	+	+	+	0	+	+	0	0	0	0	0
2758*	A^{23}/a B^{15}/b	0	+	+	0	0	0	+	0	0	0	+
2776*	A^{23456}/A^{23} B^3/B^4	0	+	+	+	+	+	0	0	+	+	0
P178	a/a B^{25}/b	0	0	0	0	0	0	0	+	0	0	+
P827	a/a B^{15}/B^{25}	0	0	0	0	0	0	+	+	0	0	+
R404	A^{123}/A^{23456} B^3/b	+	+	+	+	+	+	0	0	+	0	0
R405	A^{23}/a B^{15}/B^4	0	+	+	0	0	0	+	0	0	+	+
R407	A^{23}/a B^4/b	0	+	+	0	0	0	0	0	0	+	0
R409	A^{123}/A^{23456} B^{25}/B^4	+	+	+	+	+	+	0	+	0	+	+
R426*	A^{23456}/a B^{15}/B^3	0	+	+	+	+	+	+	0	+	0	+
R427*	A^{23}/A^{23} B^{25}/B^3	0	+	+	0	0	0	0	+	+	0	+
R439*	A^{123}/A^{23456} B^4/b	+	+	+	+	+	+	0	0	0	+	0

* Indicates that the bird is a male.
The symbols (+) and (0) indicate the presence and absence of agglutination, respectively.

parent to transmit with equal frequency the genes at either locus to both sexes of the progeny, as indicated by the genotypes (determined by progeny test) of the males and females of table 6.

Possible linkage relationships between the A or B loci and the loci of other known autosomal marker genes have been investigated only with regard to dominant white (I). From the mating of a white crossbred female of the genotype A^{23456}/A^{23} B^3/b I/i to a Barred Plymouth Rock male of the genotype A^{23}/A^{3} B^{15}/b i/i there resulted 36 progeny in which dominant white (I) segregated with respect to the A and B loci in a manner not significantly different from that expected as a result of independent assortment. Thus, even though the number of progeny was small, it can be tentatively concluded that the locus for dominant white is on a third independent chromosome, although the present data do not exclude the possibility of loose linkage.

DISCUSSION

The apparent serological complexity of the "A" series of agglutinogens (A_{23}, A_{123}, A_{23456}, etc.) may be accounted for, according to one explanation, by

assuming that the antigenic factors (A_1, A_2, A_3, etc.) are each due to individual genes, very closely linked so that the various antigenic factors appear to be inherited in certain constant combinations. For example, the "antigenic complex" A_{123} may be inherited as a unit because of very close linkage between the genes producing each of the antigenic factors A_1, A_2 and A_3. This hypothesis presupposes that crossing over does occur between the genes responsible for these antigenic factors and should eventually be observed. Cases of closely linked genes having similar effects have been reported in Drosophila (LEWIS 1945, 1948; and GREEN and GREEN 1949), maize (LAUGHNAN 1949), cotton (STEPHENS 1948, YU and CHANG 1948) and mice (DUNN and CASPARI 1945). On the other hand, the data obtained in these studies may be explained rather simply by hypothesizing that each "antigenic complex" is produced by one of a series of alleles. For example, the single gene, A^{123}, produces an antigenic substance or substances capable of reacting with each of the serological reagents—A1, A2 and A3.

The multiple allele hypothesis could account for the antigenic complexity in either of two ways, depending on the type of gene action presumed to be predominant. Pleiotropic activity on the part of the individual alleles of the series may be assumed; that is, each allele is capable of producing several particulate antigenic substances. For example, allele A^{123} could be viewed as producing three separate antigens—A_1, A_2 and A_3—each of which is reactive with a different reagent. The other type of gene action by which a series of alleles could account for the A series of agglutinogens is based upon the assumption that each allele produces a particulate antigenic substance which is very similar to, yet chemically distinct from, the antigenic substances produced by the other members of the series. This means that a reagent prepared against the antigenic substance produced by one member of the allelic series will frequently cross-react with the antigens produced by one or more of the remaining alleles.

Fundamental work on the specificity of antigens and antibodies (reviewed by LANDSTEINER 1945) shows that in response to the injection of a relatively simple conjugated antigen there results a multiplicity of antibodies of varying specificity, all of which are reactive with the homologous antigen, but show graded affinity for chemically related substances. That an array of antibodies of varying specificity may be produced against a natural antigen is clearly demonstrated by the results obtained by PERLMAN and GOEBEL (1946) with highly purified somatic antigens of the Flexner group of dysentery bacilli. Considering these findings along with the similar effects characteristically produced by allelic genes, it is reasonable to expect that certain portions of the array of antibodies formed against an antigen produced by one allele would frequently cross-react with antigens determined by other alleles of the same series. For example, as a result of the injection of red cells containing antigen A_{23456} into an individual whose cells possessed A_{23}, there were formed antibodies which, in addition to agglutinating cells possessing the immunizing antigen A_{23456}, reacted with cells possessing the antigen A_{1236} or A_{2346}. Thus, the apparent antigenic complexity of many red cell antigens may simply reflect the serological phenomena associated with the production of antibodies and their ensuing cross-reactivity with similar, yet chemically distinct, antigens.

Groups of antigens resembling in serological complexity those reported here for the chicken are known to exist in other species of mammals and birds. In man the linked gene hypothesis has been advanced by FISHER (1944) and FISHER and RACE (1946) to account for the serological complexity of the Rh blood group factors. On the other hand, the complexity of the Rh group has been accounted for on the basis of multiple allelic genes by WIENER and LANDSTEINER (1943) and WIENER (1943, 1944, 1949). The recent studies of WIENER and GORDON (1949) and WIENER, UNDER and MAZZARINO (1949) on the rh^w factor, a new variant of the Rh group, strongly indicate that the type of serological and genetic diversity displayed by the Rh factors is very similar to, if not identical with, the antigenic characters reported in this paper. The discovery of a third antigenic factor (S) belonging to the MN group of agglutinogens of man (WALSH and MONTGOMERY 1947, SANGER and RACE 1947) has prompted RACE, SANGER, LAWLER, and BERTINSHAW (1949) to prefer the linked gene hypothesis over the multiple allele explanation in accounting for the four constantly inherited antigenic combinations M, MS, N and NS, although the latter hypothesis appears to be simpler and adequate to explain the results obtained.

In cattle there exist at least two series of serologically related antigens for which either the linkage or multiple allele hypothesis could be advanced; however, in view of the consistency with which the various combinations of antigenic factors are inherited as units the multiple allele hypothesis has been given preference by STORMONT, IRWIN and OWEN (1945) and STORMONT, OWEN and IRWIN (in press). MCGIBBON (1944, 1945) has reported that a group of serologically related antigens also exists in Muscovy ducks. Here, as with the other species mentioned, the antigenic factors appeared to be inherited only in certain combinations, indicating that unitary inheritance, regardless of species, of antigenic factor combinations seems to be a universal rule applicable to all of the extensively studied groups of serologically related red cell antigens.

In view of this common finding, together with the known facts relating to the diversity of antibody production and the cross-reactivity of antibodies with substances similar to the homologous antigen, it is felt that the multiple allele interpretation offers the most acceptable working hypothesis on which to base future work on the cellular antigens of the chicken.

SUMMARY

These studies show that two independently inherited groups of agglutinogens are present in the erythrocytes of the chicken. In view of the serological and genetic data presented, it has been hypothesized that the antigens so far detected are determined by genes belonging to one or the other of two autosomal series of multiple alleles. One of these consists of 9 and the other of 5 members. The type of action displayed by the alleles of each series indicates a complete lack of dominance, in that each allele produces its particular antigenic substance, regardless of the other alleles that may be present.

The antigenic products of many of the alleles have multiple serological properties. To facilitate discussion of this complex situation the total antigenic

product of each allele has been uniformly referred to as an antigen and the serological components which appear to constitute the antigens are designated as "antigenic factors." It is thought that these factors as they appear in the antigens produced by various alleles are probably indicative only of serological similarity existing between respective gene products and do not in themselves represent separate and discrete antigenic units.

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ABSTRACTS OF PAPERS PRESENTED AT THE 1950 MEETINGS OF THE GENETICS SOCIETY OF AMERICA

COLUMBUS, OHIO, SEPTEMBER 11 - 14, 1950

ATWOOD, S.S. and J.L. BREWBAKER, Cornell University, Ithaca, N.Y.: Multiple oppositional alleles in autoploid white clover. — In a previous report (Proc. Nat. Acad. Sci. 30: 69-79. 1944), colchicine-induced, autoploid sectors of Trifolium repens L. were described as self-incompatible like the 32-chromosome plants upon which they arose. An F_1 family from two such 64-chromosome plants consisted of 3 self-incompatible and 26 self-compatible plants. When the latter were used as males, all inter-crosses and backcrosses were compatible. When the parents and self-incompatible F_1 plants were used as males, both compatible and incompatible matings were found. This study has been extended to 16 F_2 families involving a total of 559 plants obtained by selfing or intercrossing F_1 plants and parents. The F_2 families segregated into the expected ratios of SI:SC plants. In addition when the F_2 plants were crossed with the self-incompatible parents and F_1 testers, the incompatibility reactions conformed to those of the F_1. All results are explained by assuming that homozygous diploid pollen behaves as haploid pollen in the regular oppositional manner, whereas heterozygous diploid pollen either functions or fails depending on "dominance" or "interaction" relations of the S alleles in each pollen grain. The four alleles from the two original parents appear to have the following dominance relationship: $2 > 3 > 4 > 1$. The genotype S_2S_4 is the only one showing interaction in the pollen. All plants producing this class of pollen are not only self-compatible but cross-compatible in all combinations when used as male. Varying degrees of self- and cross-compatibility can be explained by the proportion of functional pollen and by the degree of dominance in the heterozygous pollen.

BERTANI, G., University of Illinois, Urbana, Ill.: Streptomycin resistant bacterial mutants in the study of lysogenicity. — Titration of bacteriophage liberated by lysogenic bacteria has been done in the past either by separating bacteria from phage by means of centrifugation or by selectively heat-killing the bacteria, the phage not being inactivated by this treatment. Very good results have now been obtained using for titration an indicator strain resistant to streptomycin. Plating for free phage is done with the usual soft agar technique: the mixture of lysogenic

bacteria sensitive to streptomycin (Escherichia coli, Lisbonne-Carrere strain) and free phage produced by them is plated at a suitable dilution against the indicator strain (a streptomycin resistant mutant of Shigella shigae) in presence of an amount of streptomycin which kills off in a very short time the sensitive lysogenic bacteria, but does not inactivate free phage particles. These particles can infect the streptomycin resistant cells of the indicator strain and form visible plaques. Control assays, done with the centrifugation method, always gave titers identical with those obtained by the streptomycin method. This method is now used in studying quantitatively the process of phage liberation by lysogenic strains of bacteria. Since sensitivity to streptomycin and ability to mutate to resistant forms are very common in bacteria, the method here described may be easily applied to other lysogenic strains of bacteria.

BISHOP, C.J., Acadia University, Wolfville, Nova Scotia, Canada: The influence of polyploidy on the X-ray sensitivity of cells. – A study of comparative sensitivity to x-radiation has been made by treating developing microspores and pollen grains of diploid and tetraploid species of Tradescantia with equal doses of x-rays. Treatments were given at a time just previous to the prophase of the pollen grain division and at a stage before chromosome doubling in the generative nucleus division. The aberrations produced were analysed at the pollen grain division and the pollen tube division respectively. Results indicate that the sensitivity of the two types of cells is the same if the comparison is based on the number of x-ray-induced breaks per chromosome. A comparison of the number of breaks per cell shows that the cells from the tetraploid plants have approximately double the number of breaks found in those from the diploid plants.

BLANCO, J.L., Mision Biologica de Galicia, Pontevedra, Spain, (University of Minnesota, St. Paul, Minn.): Pollen size and quantitative inheritance. Crossingover in inbred lines of Drosophila melanogaster. – "Pollen size and quantitative inheritance in maize", Blanco, J.L. Pollen size analysis in hybrids, varieties and inbreds seems to indicate that pollen of inbreds has a smaller range in size but a larger mean size than pollen of hybrids and varieties. Pollen size analysis of two stocks, each with one ring of 8 chromosomes (translocation 1-5-7-6, Professor C.R. Burnham's material) and their corresponding parents seems to indicate: – a) The normal parent stock and the homozygous translocation parent have unimodal distinctive distribution of pollen size. b) Normal pollen in F_1 plants with the 8-chromosome ring, seems to indicate bimodal size distribution in certain plants, as expected from segregation into two classes representing the translocation and the normal complements. – As far as tested, no significant influence of environment on pollen size has been found. – It is hoped that analysis of pollen size and behaviour may be one way to analyze inheritance of quantitative characters of plants or predict the behaviour of lines. Experiments are in progress to study

pollen size in relation to combining ability and the possibility of selective action on pollen by distinctive pollen behaviour. — "Crossing-over in inbred Drosophila", Blanco, J.L. and M. Garcia. Heterozygous $\frac{Y\ w}{+\ +}$; $\frac{Y\ B}{+\ +}$ and $\frac{rb\ m}{+\ +}$ were carried on inbreeding from F_1 to F_{15} (Brother sister mating). The crossover percent seems to increase in the early generations. After the 8th generation progressive and strong reduction of crossover percents was observed, resulting in the following averages for generation 9th to 15th:

Y w = 0.62% Y w = 0.62 % ; YB = 27.20 % ; rb m = 3.12 %.

BOHREN, B.B., Purdue University, Lafayette, Ind.: A sex-linked nervous disorder in the fowl and its linkage relationship. — A condition in day-old chicks referred to as "Jittery," in which the head is retracted over the back, accompanied by a rapid shaking of the head has been studied. The character is highly lethal in post embryonic stages with approximately one percent of affected females reaching maturity. In adult hens the expression of the gene is similar to that in chicks and in addition they tend to circle rapidly when frightened. Breeding tests whos the gene for jittery to be a sex-linked recessive. Males heterozygous for jittery, barring and rapid feathering were mated with females that were black, slow feathering and non-jittery to test for linkage. Since the slow feathering and non-jittery genes of the females are dominant, only the female offspring were studied. A total of 504 female chicks were classified and no evidence was found for linkage of jittery with either barring or rapid feathering. Barring and rapid feathering are nearly at opposite ends of the known sex chromosome map, but it is unlikely that jittery could lie between them and still show linkage with neither. If jittery is located distally on the chromosome from either of the other genes it appears that the X-chromosome of the fowl is longer than has been indicated by previous evidence.

BONNER, D.M., Yale University, New Haven, Conn.: The Q locus of Neurospora. — Recent experimental evidence suggests that certain genes in Drosophila and corn exhibit a complex genetic structure. Preliminary data of a similar kind have now been obtained for a locus in Neurospora crassa controlling a single biochemical reaction. Strain 3416 requires niacin, is unable to utilize any known niacin precursor, and accumulates quinolinic acid. This locus is called the Q locus. Three independent Q locus mutants are known, strains 1-(3416), 2-(Y-30166), 3-(Y-31873). As a test of biochemical identity, heterocaryons were formed between these strains, using double biochemical mutants and forcing heterocaryon formation in the presence of niacin. Each of the formed heterocaryons remained niacin dependent. Crosses were made in all combinations with these strains. Serial isolation of ascospores gave only parental cultures. Isolation of whole perithecia (ca. 250 ascospores/perithecium), however, gave occasional niacin-independent cultures, the frequency (per 100 perithecia) of which depended on the

cross as follows: 1 x 1 - 0.5, 2 x 2 - 0, 3 x 3 - 0, 1 x 2 - 10, 1 x 3 - 2, 2 x 3 - 0. Though the data at present do not prove that these niacin independent cultures result from crossing over, they strongly suggest that these "alleles" represent three closely linked units, all of which must be present in the same linkage group for expression of the Q locus in niacin formation. These units appear genetically as three closely linked genes. Biochemically, however, they appear as three component parts of a larger unit which is necessary for the performance of a single specific reaction characteristic of niacin formation.

BOWEN, C.C. and G.B. WILSON, Michigan State College, East Lansing, Mich.: Some factors correlated with differential reactivity in the somatic chromosomes of Trillium. — In the course of a series of studies designed to throw light on the phenomenon of the appearance of localized secondary constrictions in somatic chromosomes of Trillium and other organisms after treatment at 2°C, a series of Fuelgen squash preparations of root tips of Trillium sessile L., treated for from 24 to 120 hours at 2°C, were studied quantitatively. It was found that the apparent degree of differential reactivity was in inverse proportion to the degree of contraction shown by the undifferentiated portions of metaphase chromosomes. On the other hand, this degree of differentiation was found to vary directly as the duration of cold treatment and the relative frequency of division figures.

BRAUN, W., R. GOODLOW and M. KRAFT, Camp Detrick, Frederick, Md.: The role of metabolites in bacterial variation. — The application of paper partition chromatography to studies on population changes in broth cultures of Brucella spp. has revealed that the concentration of alanine, accumulating as an end product of the cells' normal metabolism, determines which one of various antigenic and "colony-type" mutants may establish itself at different times in the culture's growth. These mutants differ in their susceptibility to toxic effects of alanine; continuous population changes in the presence of increasing metabolite concentrations thus are due to the progressive establishment of mutants with increasing alanine resistance. Because of quantitative differences in alanine production by different mutant types, the initial proportion of a given mutant in a mixed inoculum will determine the ability of the mutant to establish itself during the culture's growth. Data illustrating these interactions will be presented. Certain environmental agents which prevent population changes appear to affect alanine production. — Preliminary data indicate that these phenomena may be of general significance for population changes in various bacterial species.

BRILES, W.E., Texas Agricultural Experiment Station, College Station, Texas: Antigenic differences between inbred lines of chickens.— Five inbred lines of chickens (50 to 70 percent inbred) have been distinguished from each other by means of the antigens present in their red cells. Of the five lines utilized in this study four were Single Comb

White Leghorns and one was a New Hampshire. The New Hampshire line and two of the Leghorn lines were supplied by the University of Minnesota, while the other two Leghorn lines were developed by the Texas Agricultural Experiment Station. The serological reagents used in detecting the antigens were prepared by iso-immunization in which the members of the Texas lines were injected with the blood of individuals belonging to the same line or with the blood of hybrids between the Texas lines. Following this general procedure, nine serological reagents were prepared which agglutinated the red cells of some or all of the inbred lines. Antigenic differences between the five inbred lines were detected by testing the cells of each line for agglutination with each of the nine reagents. The antigens identified in this study appear to be produced by the independent action of genes at three loci. Although among these lines heterozygosity is widespread at the loci effecting the red cell antigens, the cells of each line can be distinguished from those of each of the other lines by comparing the reactions obtained with the various reagents.

BROWNING, I., LAURALEE R. SWINFORD and NONA B. VARNEDOE, M.D. Anderson Hospital for Cancer Research, Houston, Texas: Environmentally induced long-term modification of generation time in the protozoan Tetrahymena geleii (T-P). — Protozoa were cultured in normal liquid media and agar media of the same chemical constitution. Colonies were isolated from agar and grown in liquid by serial transfers. Comparative population studies were made with control and experimental organisms. The latter were found to have a greatly increased generation time which returned to normal over a period of many generations. Growth of normally free-living protozoa on agar reversibily modified morphology to a disc shape. The disc shape permits a maximum area of exposure to agar with a corresponding access to food and salts. These surface-living protozoa are afforded unusually ready access to the air; therefore, a higher than usual oxygen tension is probably maintained in the organisms. Viscosity appeared to be considerably increased in the agar-living forms as judged by decreased Brownian motion. This observation led to the doubling of calcium in the agar media in an attempt to antagonize the viscosity increase. An accelerated growth rate resulted. — These results indicate a dehydrating effect by agar, and a probable increase in concentration of enzymes and solutes. A new enzyme-balance is probably established due to protoplasmic dehydration and differential diffusion rate of Proteose-Peptone and inorganic molecules through agar. This hypothetical new enzyme-balance is associated with slow reproduction rate, and is hereditable in decreasing proportion up to one hundred generations after reisolation from agar to liquid.

BRYSON, V., Biological Laboratory, Cold Spring Harbor, N.Y.: Photo-stimulation of E. coli mutants resistant to streptomycin.

Irradiation of saline suspended Escherichia coli cultures with a mercury vapor ultraviolet lamp and subsequent plating in nutrient agar containing .03% glucose and 10 μg streptomycin per ml results in a large absolute increase in the number of colonies compared with unirradiated controls after three days incubation at 37°C. The populations to be irradiated have titers in the order of magnitude of $5x10^8$ or more cells per ml and are derived from saturated cultures grown in synthetic media (M9). The absolute increase in colonies recovered in streptomycin media following irradiation is evident with increased ultraviolet dosages to the 0.1% survival level, and is dependent primarily on direct photo-stimulation of a poorly viable mutant component of streptomycin resistant cells undetected in control preparations plated in equivalent high titers. Existence of the poorly viable component of streptomycin resistant cells may be demonstrated independently by plating progressively decreasing numbers of cells in 10 μg of streptomycin per ml of nutrient agar supplemented with traces of carbohydrate. It is then seen that over a range of from 10^{10} to 10^8 cells per ml a decrease in the number of untreated bacteria plated in streptomycin results in an absolute increase in the number of streptomycin resistant colonies of variable size that grow through. Thus fewer colonies are observed when $1.5x10^{10}$ cells are plated in streptomycin media than when $2.4x10^8$ bacteria are taken from the same culture and similarly exposed to the selective action of streptomycin. The combined action of radiation and traces of hexoses and polyhydric alcohols in unmasking the hidden mutants suppressed in untreated crowded cultures is independent of a previously reported antagonistic effect of carbohydrates on streptomycin. Following ultraviolet treatment, the emergence of bacterial mutants that are not induced but are merely of increased vaibility suggests that conventional experiments on mutagenic agents may involve such such factors as modified selective pressures of the experimental environment, or modified growth potentials of variants that are relatively inviable in the untreated population.

BURDETTE, W.J., Louisiana State University, New Orleans, La.: Comparison of mutation rate and tumor incidence in Drosophila treated with chemicals.* — In previous studies it was found that 20-methylcholanthrene did not increase the lethal mutation rate in Drosophila. This is contrary to expectations if it is assumed that this chemical is carcinogenic because of mutagenic activity. It is possible that it is neither carcinogenic nor mutagenic in this species, thus explaining the discrepancy between results and expectations. This can be tested by utilizing a tumor strain of Drosophila. Any change in tumor incidence may then be detected at the same time mutation rate is determined. The stock selected for the study was tu 36a. Fifty males and 50 virgin

*This project was supported by a grant from the National Cancer Institute, U.S. Public Health Service.

females were treated with an aerosol of 20-methylcholanthrene. The offspring were carefully examined for tumors, and F_1 females were tested for lethals of the X chromosome by the Muller-5 method. There were 63 tumors among 1622 treated flies and 17 among 1650 which were not treated. In contrast to this increase in tumor incidence the lethal mutation rate in the treated group was unchanged. It was 0.26% in those treated and 0.20% in those untreated. In the former group 1912 chromosomes were tested, and in the latter there were 2041 tested. A similar series of experiments using methy-bis(betachloroethyl amine)hydrochloride for the chemical treatment resulted in a significant increase in both mutation rate and tumor incidence. Thus, although certain chemicals may increase both, tumor incidence may be elevated without a corresponding change in lethal mutation rate.

BURNHAM, C.R., University of Minnesota, St. Paul, Minn.: Crossingover in an inversion heterozygote. — In maize a stock homozygous for translocation 5-6c (.89 long arm of 5 and adjacent to the centromere in the short arm of 6) and heterozygous for the pericentric inversion 5a (.67 long arm and near the centromere in the short arm of 5) has a chromosome pair which is heterozygous for the inversion and attached to the nucleolus. Spore quartets with two spores having diffuse nucleolar material (no organizer) are expected only as the result of 4-strand double crossovers within the inversion. Of 1744 quartets, only 0.9% were of this type, indicating a low frequency of double crossing over. Crossing over in plants heterozygous for both T5-6c and In5a; type 1 with the inversion in the normal chromosome, type 2 with it in the translocated chromosome 5: In type 1:, there were 45% of "crossover type" quartets while in plants heterozygous for T5-6c and not carrying the inversion there were 63%. The reduction appears to be due largely to a decrease in the frequency of multiple crossovers within the inversion. In plants of type 2, 12% of crossover type quartets were observed. Only crossovers between the inverted centromere and the translocation point of 5 were detectable. This value is comparable with the 11% observed in plants heterozygous for T5-6c but homozygous for the inversion, and indicates no reduction in crossing over in this region adjacent to the heterozygous inversion.

CAMERON, J.W., ANNA NEWTON and H.J. TEAS, University of California at Riverside and California Institute of Technology, Pasadena, Calif.: Carbohydrate, auxin, niacin, and tryptophane in developing kernels of sugary and starchy maize. — The sugary gene (su_1) as contrasted with its normal allele (Su_1) produces marked differences in the content of endosperm carbohydrates and niacin. Relationships between niacin, tryptophane, and indolacetic acid (auxin) in other plants prompted studies of these substances together with carbohydrates in developing kernels. Two series were collected: in the first su and Su were segregating on the same ears; in the second, Su seeds were obtained from a standard line, KYS, and su seeds from a su KYS conversion. Ontogenetic

stages for assay were preserved by freezing and lyophilization. Based on amount of substance per kernel, sucrose was higher in su than in Su from 16 days after pollination on; water soluble polysaccharides became increasingly higher in su after 16 days; and reducing sugars showed little difference. Niacin increased in both genotypes from 12 to 28 days and was consistently higher in su. Total auxin increased rapidly and was similar in amount in su and Su from 16 to 28 days. Tryptophane levels were also similar for su and Su in the KYS series through 32 days; in the other series su endosperms were consistently higher after 18 days. However, tryptophane content varied widely among homozygous Su lines with theoretically similar backgrounds. These data extend our knowledge of the developmental effects of the su and Su alleles. The simultaneously higher content of sucrose, water soluble polysaccharides and niacin in su from about 16 days on suggests a functional relationship among these sbustances.

CASPARI, E. and W.E. WESTOVER, Wesleyan University, Middletown, Conn.: Developmental potencies of brachyury tails in the mouse.— In mice carrying the gene Brachyury in heterozygous condition, the distal part of the tail does not contain a notochord, and finally degenerates and is lost. Tails of normal and Brachyury embryos 11-13 days old were transplanted into the anterior chamber of the eye of adult normal mice. The transplants survived and grew, and were fixed and sectioned 5 days after the operation. Differentiation was found in tails of both genotypes. Normal tail pieces formed notochord, tailgut, cartilage surrounding the notochord, in some cases neural tube and an abnormal differentiation which may be called "lentoid tissue." Brachyury tails formed cartilage, tailgut and lentoid tissue but in no case was a notochord or neural structures found in the transplants. Lentoid tissue was also found. These data seem to indicate that Brachyury tails can survive in spite of lack of a notochord, and that therefore lack of the notochord is not directly responsible for the degeneration of the tail. They further demonstrate that the formation of cartilage is not dependent on the presence of a notochord. There is some evidence, however, that the organization of cartilage into vertebrae may be dependent on the presence of the notochord. The shape of the cartilage appears to be influenced by the situation of the well-developed tailgut.

CLANCY, C.W. and F.L. CHAN, University of Oregon, Eugene, Ore.: Comparative chromatographic analysis of the "red" eye pigment in the vermilion group of mutants of D. melanogaster. — The "red" eye pigment derived from vermilion has been shown to fractionate into ten closely related colored entities by partition chromatography on silica gel with wet butanol. In addition, we have more recently found that four fluorescing bands are regularly detectable on our chromatograms when observed with ultra-violet light (Corning filter H.R. Red Purple Ultra No. 587) under certain standardized conditions. We have now critically compared inter se chromatograms of the relatively purified pigment

from the mutants vermilion, cinnabar, scarlet, and cardinal, and find all of them to be essentially the same. Our data indicate that the end-product(s) of the action (or lack of action) of these mutant genes is identical qualitatively in spite of evidence for the existence of quantitative differences in pigment content between the mutants in respect to the pigment complex as a whole.

CLARK, A.M. and C.J. MITCHELL, University of Delaware, Newark, Del.: Gene dosage relations in Habrobracon. — The normal occurrence of haploids and diploids in Habrobracon offers an opportunity to study the expression of mutant genes in the haploid and diploid state. Comparison can then be made between mutants in double dose in the diploid state and the same mutants in the haploid state. The wild type and ten mutant types were studied in haploid males, diploid males, and diploid females. The mutants studied affected antennal length, wing length, wing scalloping, eye size, head size, and wing venation. Comparison of wild type haploid and diploid males reveals no marked gross structural differences, but statistical differences do exist. Comparison of mutant haploid and diploid males shows that for some mutants there is an increased effect in the diploid state while for other mutants there is not. Thus, conditions of genic balance hold for some genes, but not for others. Three of the mutants studied showed marked differences between haploid and diploid males. These three genes had in common a shortening effect upon antennae. Thus, the mutants which showed a marked increase in gene dosage in the diploid state were mutants affecting the same structure in the same way.

DAVIS, B.D., U.S.P.H.S., Cornell University Medical College, New York, N.Y.: Phenomic delay in radiation-induced reversion of E. coli auxothrophs to nutritional independence. — We have reported, in connection with the penicillin method, that phenotypic expression of UV-induced auxotrophic mutations requires growth. UV-induced reversions (without reference to genetic location) have given similar results. Tryp$^-$ strain 19-2, irradiated in washed suspension (survival 50% to 1%) and plated on minimal medium, shows little induced reversion. A trace of tryptophan (0.002-0.1 γ/ml.), however, produces up to 300-fold increases in reversion rate with irradiated inocula, but none with unirradiated controls. Similar effects of trace enrichment have been obtained with other amino acid, purine, and vitamin auxotrophs. The phenomenon could be due to requirement of growth for the action of a mutagen produced by UV irradiation. Similar delay, however, is encountered with X-irradiation, which, in contrast to UV, does not produce a photochemically reversible mutagen. True phenomic delay therefore appears more likely, according to which the gene has mutated but cannot start to form the previously deficient enzyme until the cell is supplied with the product of that enzyme. This "pump-priming" effect implies that the metabolic turnover of the non-growing cell fails to provide a substrate, or exhaust an inhibitor, of some reaction essential for the

synthesis of the previously deficient enzyme. With most strains reversions are heterogenous with respect to growth rate, as are prototrophs obtained by genetic recombination. Reversions were induced by irradiation in all auxotrophs studied, but not in a lac$^-$ strain (Lederberg's Y-87) with a spontaneous reversion frequency of 2×10^{-6}, despite the opportunity for phenomic development. No explanation is available.

EATON, O.N., U.S. Department of Agriculture, Beltsville, Md.: Effect of heterozygosity of dams and litters on characteristics of offspring in mice. — Comparison was made between mice born in inbred strains with F_1 populations from these strains and with outbred, outcross and topcross mice to determine the effects of heterozygosity upon various characters. The above types of matings determine different levels of heterozygosity of dams and litters. The characters studied were number of mice born alive, number alive at 15 and 45 days, total litter and individual mouse weights at 15 and 45 days. The greater heterozygosity of F_1 crosses than of inbred mice accounted for more than 2 extra mice per litter at birth, 15 and 45 days. Number of mice per litter due to greater heterozygosity of dams whowed only slight advantage over that of inbred dams. This leads to the assumption that greater litter size is due more to greater survival among heterozygous mice than to ovulatory capacity of dams. Total litter weight at 15 and 45 days was greater in the more heterozygous litters. The difference could be accounted for mainly by the difference in number of mice at these ages. Individual mouse weight in the more heterozygous litters was greater by 0.3 gm. at 15 days and 2.8 gm. at 45 days. Total litter weight at 15 days for the more heterozygous dams showed an increase of 4.3 gm. over that of inbred dams. Individual mouse weight was 0.75 gm. greater at 15 days for heterozygous dams, due presumably to the dam's greater milking capacity. At 45 days after the mouse is weaned, this effect was practically zero.

EIGSTI, O.J., Funk Bros. Seed Company, Bloomington, Ill.: Colchicine and related compounds compared for C-mitotic activity. — Colchicine and derivatives of it were studied for toxicity and C-mitotic activity by the pollen tube-culture technic. More derivatives of colchicine and other compounds with similar effects become available with the increased interest in the biological effects of colchicine, as well as other substances. Generally the new compounds tested show greater toxicity and lesser C-mitotic action. Trimethylcolchicinic acid methyl ether d-tartrate (supplied through courtesy of Smith, Kline and French Laboratories, Phila., Pa.) was more effective upon mitosis than another group of compounds made available for these comparisons. (Compounds were supplied by J.G. Klein and A.S. Hussey, Northwestern, Evanston, Ill.) The differences between colchicine and TMCA methyl ether were only slight as determined by these tests. Details regarding structure of compounds and results obtained are given at the demonstration.

EVERETT, H.L., Connecticut Agricultural Experiment Station, New Haven, Conn.: A proposed relationship between suppressor gene mutants and heterosis. — In the course of study concerned with chlorophyll formation in Zea mays inbreds, several suppressor gene mutants have been isolated. These genes overcome to a greater or lesser degree the effects of a pleiotropic gene causing light endosperm color and plant albinism in the homozygous recessive state. The widespread occurrence of these suppressor gene mutants overcoming the deleterious effects of the pleiotropic gene under consideration suggests that in hybrid combination the genome often allows for alternate pathways leading to the formation of the chloroplast in this case. When inbreeding takes place, blocks of homozygous recessive loci drastically limit the biosynthetic pathways and plant vigor is reduced. Combining the inbred genomes, as in the formation of maize hybrids, results in a re-establishing of many alternate pathways of synthesis and allows for a more favorable adaptability of the organism to environmental changes. This adaptability is manifest phenotypically as hybrid vigor or heterosis. This hypothysis is based on the assumption that suppressor gene mutants are common for a majority of gene actions and that such suppressor genes are of importance in allowing a maximum effort of the organism to survive and prosper in its given environment. Such an assumption is quite amenable to experimental test.

FABERGÉ, A.C., University of Missouri, Columbia, Mo.: Relation between the action of cold and of nitrogen in decreasing the frequency of chromosome aberrations. — Two methods drastically reduce chromosome breaks produced by X-rays in Tradescantia. One can irradiate at a very low temperature (Faberge, 1948, Genetics 33:609) or in the absence of oxygen (Thoday and Read, 1947, Nature 160:608; Giles and Riley, 1949, P.N.A.S. 35:640-646). The order of magnitude is the same. There is a parallelism between the amount of H_2O_2 produced by X-rays at various low temperatures and chromosome sensitivity (Faberge 1950, Genetics 35:104-105); H_2O_2 production also depends on oxygen. Experiments are now reported in which both agencies are applied, the material being Tradescantia pollen, later germinated to observe tube mitoses. Pollen was placed in a stream of either dry air or nitrogen, at room temperature, for 10 minutes before irradiation. During irradiation the gas streams continued. Nitrogen reduces sensitivity if irradiation is conducted at +20°C, but has no detectable action if irradiation is done at -191°C. It is the writer's view that information accumulated from the irradiation of Tradescantia shows the traditional antithesis between direct and indirect action to lack realism. Experiments with oxygen and with extreme cold strongly suggest an indirect chemical step. This might represent spread of effect around an ionisation cluster. In terms of formal Target theory, a factor of 5 x in sensitivity represents a change of only 1.7 x in linear dimensions, so that there is no occasion to abandon geometrical theories, at least in principle.

FORD, LEOLA E., Ohio State University, Columbus, Ohio: A genetic study involving male sterility in Coleus. — Lobing and male sterility in Coleus have been shown to be due either to a series of alleles or two closely linked genes (Rife, 1940, 1944). Four types of plants would be possible if two closely linked genes were involved, viz. deep lobed male fertile, deep lobed male sterile, shallow lobed male fertile, shallow lobed male sterile. No shallow lobed male sterile plants have been obtained. Repeated crosses between heterozygous deep lobed male sterile plants and homozygous shallow lobed male fertile plants have produced deep lobed male sterile and shallow lobed male fertile plants only, strengthening the multiple allele theory. However, in progeny of one such cross made in the fall of 1949, there appeared one deep lobed male fertile plant from which seed has been obtained by selfing and outcrossing. The appearance of this crossover plant strengthens the theory of two closely linked genes. Additional crosses have been made to test further these two theories, and the possible appearance of a shallow lobed male sterile plant would help to establish the theory of two closely linked genes.

FOX, A.S., and W.D. GRAY, Ohio State University, Columbus, Ohio: Enzymatic (tyrosinase) differences between the mating types of strain 15300 (albino-2), Neurospora crassa. — Analysis of a hitherto unreported difference between the two mating types of Strain 15300, Neurospora crassa, has demonstrated that a tyrosinase is present in 15300a but not in 15300A. Aged cultures and homogenates of 15300a, but not of 15300A, exhibit the development of a brown or black pigment. The absorption spectrum and chemical characteristics of the pigment identify it as melanin. Spectrophotometric measurements of the optical densities of centrifuged homogenates provide the following observations: (1) Homogenates of 15300a exhibit a spontaneous but limited production of melanin; (2) After the optical density of 15300a homogenate reaches a constant value, there is a resumption of pigment formation with addition of proper substrate; (3) Both tyrosine and dopa are utilized as substrate; (4) Rate of pigment formation depends on both substrate and homogenate concentration; (5) Activity of homogenates declines with age; (6) pH and electrolyte concentration affect the activity; (7) Boiled homogenates exhibit no activity; (8) Addition of 15300A homogenate to 15300a homogenate results in increased pigment production; (9) Seitz filtration of 15300a homogenates results in marked reduction of their activity. It is concluded that, whereas both mating types posses suitable substrate, 15300a possesses a tyrosinase not possessed by 15300A. This enzyme may be associated with small cytoplasmic particles, such as mitochondria or microsomes. While preliminary crosses have not resulted in recombination between the tyrosinase and mating type, sufficient genetic data are not yet at hand to conclude that the enzymatic difference may be attributed to the mating-type locus.

FOX, A.S. and W.D. GRAY, Ohio State University, Columbus, Ohio:

Antigenic differences between the mating types of strain 15300 (albino-2), Neurospora crassa. –Antisera against homogenates of 15300A and 15300a, and against homogenates of single-ascospore cultures of the two mating types resulting from a cross between 15300A and 15300a ("F_1-A" and "F_1-a"), have been produced by intraperitoneal injection of rabbits. Absorptions and precipitin-ring tests of these antisera have been performed, utilizing Seitz-filtered homogenates as antigens. These tests demonstrate that 15300A possesses an antigenic fraction not possessed by 15300a, and that 15300a possesses an antigenic fraction not present in 15300A. F_1-A and F_1-a both possess portions of the 15300A-specific fraction, but F_1-A possesses a much larger portion than does F_1-a. Similarly, F_1-A and F_1-a both possess portions of the 15300a-specific fraction, but in this case F_1-a possesses a much larger portion than does F_1-A. From this evidence it is concluded that genetic differences other than that of mating type are responsible for at least part of the antigenic differences between 15300A and 15300a. However, since the antigenic structures of the F_1 cultures are still most closely related to the corresponding parental mating type, a portion of the original antigenic dissimilarity may also be due to the mating-type locus. Identification of antigenic fractions strictly attirbutable to the mating-type alleles will depend upon further investigation.

GABELMAN, W.H., University of Wisconsin, Madison, Wis.: Characteristics of the cytoplasmic factor for male sterility in maize. – The per cent of viable pollen was determined in individual florets from partially fertile plants containing the cytoplasmic factor for male sterility. A polymodal distribution was obtained when the per cent viable pollen was plotted against the frequency of its occurrence. The peaks of these distributions corresponded to the first values of Poisson series with values for m of 1/2, 1, and 2. This evidence suggests that viable pollen is produced when none of the cytoplasmic factors present (e^{-m}). This is in agreement with Rhoade's earlier data showing that the cytoplasmic factor was not transferred in viable pollen from partially fertile plants. Agreement with the Poisson indicates that the cytoplasmic factor is a whole unit or particle and gives some indication of its distribution in the plant. The reproduction of the cytoplasmic factor closely parallels chromosome reproduction. Distribution of the factor parallels chromosome distribution at mitosis but appears to be random at meiosis.

GAULDEN, MARY ESTHER and MARJORIE NIX, Oak Ridge National Laboratory, Oak Ridge, Tenn.: Effects of oxygen tension on X-ray induced mitotic inhibition. – The large neuroblast cells of the embryo of the grasshopper Chortophaga viridifasciata were given 64 r of X rays while exposed to different tensions of oxygen, namely, 100%, 21% (air), 2%, and 0% (nitrogen, carbon dioxide, or vacuum). The embryos were made into culture preparations. The number of cells in mid-mitosis (prometaphase, metaphase, and anaphase) was recorded

every 22 minutes for 6 hours after treatment. Thus the number of cells completing mitosis in a given period of time was determined, since 22 minutes is the average duration of mid-mitosis (at 38° C), and since the treatments used do not affect this duration. The results indicate that the sensitivity of mitosis to radiation is reduced when cells are irradiated at the lower oxygen tensions. In other words, the duration of the period of compete mitotic inhibition (period after irradiation during which there are no cells in the mid-mitotic stages) is shorter when cells are irradiated in 0 or 2% oxygen than when they are irradiated in 21 or 100% oxygen. Experiments are now in progess to determine the sensitivity of cells to radiation in 5 and 10% oxygen.

GERSTEL, D.U., North Carolina State College, Raleigh, N.C.: On the effect of species-foreign pollen on self-incompatible guayule. — In a number of widely scattered self-incompatible spp. (in Calamagrostis, Veronica, Primula, Galium, Taraxacum, Madia) various authors have observed seed setting on isolated single plants after pollination by "fairly remotely related species"(the expression is of Dr. J. Clausen who first called the phenomenon to my attention). The resulting plants were not hybrids but diploids of the species of the mother. From guayule (Parthenium argentatum) small progenies of this kind were obtained from two self-incompatible plants isolated with P. lyratum. A third plant which was known to have strong incompatibility alleles set no fertile seed under the same conditions. To investigate this further twelve sibs of one progeny were tested for their incompatibilities; two plants were found to be compatible with the remaining ten; the groups of two and ten were each intra-sterile. This fits a 3:1 ratio expected from selfing if one of the homozygous genotypes produced were compatible with the others - as occurs with sporophytic control and dominance. As an alternative parthenogenesis is less probable because the result differs from the expectation for unreduced parthenogenesis (only maternals) and for parthenogenesis of double eggs (1:1). Probably, P. lyratum pollen tubes weakened the incompatibility reaction of the guayule stigma.

GILES, N.H. and A.V. BEATTY, Oak Ridge National Laboratory, Oak Ridge, Tenn.: The effect of X-irradiation in oxygen under pressure on chromosome aberration frequency in Tradescantia microspores. — Inflorescences of Tradescantia paludosa, clone 5, were exposed to 400 r of X-rays at 50 r per minute in atmospheres of 5% and 10% oxygen at normal atmospheric pressure (740 mm) and at positive pressures of one, two and three atmospheres above normal. Similar exposures were made in helium and in air (21% oxygen) at normal pressure and at three atmospheres above normal. The frequencies of both chromosome interchanges (dicentrics and centric rings) and interstitial deletions were determined from slides of the first post-meiotic mitosis prepared on the fourth and fifth days following irradiation. The exposures in helium indicated that these pressures alone did not alter aberration frequencies.

Exposures in 5%, 10% and 21% oxygen at the different pressures produced abberation frequencies similar to those obtained in comparable partial pressures of oxygen. For example, the effect of 5% oxygen at one atmosphere above normal is comparable to that in 10% oxygen at normal pressure. From these and previous results it is evident that oxygen increases X-ray-induced chromosome aberrations and that the amount of oxygen present during the time of exposure determines the extent of the effect. Since no pressure effect was obtained in these experiments in the absence of oxygen, the effect of pressure in the presence of oxygen apparently is, in reality, an oxygen effect.

GOODGAL, S.H., Johns Hopkins University, Baltimore, Md.: The effect of photoreactivation on the frequency of ultraviolet induced morphological mutations in the microconidial strain of Neurospora crassa.— The frequency of morphological mutations among survivors of ultraviolet treated microconidia of Neurospora crassa was reduced by post-treatment with photoreactivating light. The effect of photoreactivation on the ultraviolet induced morphological mutation rate was similar to the effect of photoreactivating light on survival, i.e., to reduce, in effect, the dosage of ultraviolet light employed in accordance with Kelner's dosage reduction principle. The proportion of mutants among survivors of ultraviolet treated microconidia was a function of the number of survivors and was not affected by post-treatment with photoreactivating light. The reduction in the proportion of ultraviolet induced mutations cannot be due to a reactivation of non-mutants only, since the actual number of mutants surviving was increased by photoreactivation. Two alternative possibilities are suggested to explain the observed correlations between killing and mutation. Either killing is produced by lethal mutation and photoreactivation prevents the induction of mutations, or killing and mutation are due to a common mediator produced by ultraviolet and inactivated by photoreactivating light. (Supported by a National Research Council AEC Predoctoral fellowship)

GREEN, E.L., Ohio State University, Columbus, Ohio: The genetics of skeletal differences between the C57 blk and the B alb C strains of mice. — Among 463 mice of strain C (= C57 blk), 98 percent had 26 presacral vertebrae (psv), the remaining 2 percent having 25 psv or a combination of 25 on one side and 26 on the other due to an asymmetrical vertebra. Among 426 mice of strain B (=B alb C), 65 percent had 26 psv, 18 percent had 27 psv and 17 percent were intermediate between 26 and 27 psv. Both strains were inbred by more than 30 generations of brother x sister mating. of 892 mice in reciprocal F_1 populations from C x B, all had 26 psv. In combined F_2 generations, 99 percent of 1248 mice had 26 psv. In backcross F_1 x C, 97 percent of 540 mice had 26 psv, 1 percent had 25 psv and 2 percent were intermediate between 25 and 26 psv. In backcross F_1 x B, 94 percent of 954 mice had 26 psv, 3 percent had 27 psv and 3 percent were intermediate between 26 and 27 psv. The variation within the strains is assumed to be non-genetic.

The difference between the strains is inferred to be genetic because the F_1 is intermediate between C and B, the F_2 varies more than F_1 and each backcross tends to resemble the parent used in producing the backcross. It is estimated that at least three pairs of genes are required to account for the difference in psv number between the C and B strains.

GROSH, D.S., University of North Carolina, Raleigh, N.C.: The analogies between nuclear organization in ciliated protozoa and nuclear dimorphism in tissues of the parasitic wasp Habrobracon. — A study of the tissues of normal male Habrobracon prepared by the Rafalko modification of the Feulgen technique discloses striking analogies to nuclear situations found in ciliates:- (1) Within a single organism, whether protozocan type or metazoan example, two kinds of nuclei exist termed the macro- and micro- nuclei on the basis of size. In Habrobracon, macronuclei are found in larval tissue such as the malpighian tubes, the midgut, and the spinning glands (54 x 36μ), and in the adult fat body and midgut. Nuclei of the epidermis, nervous system and adult anlagen are small, even minute (1.8μ). (2) Furthermore, macro- and micro- nuclei have a common micro- origin derived in direct descent from the protozoan synkaryon (typically) or from the Habrobracon egg nucleus. (3) Differentiation into macronuclei is an irreversible process and such structures regularly fragment and disappear; for ciliates during autogamy, hemixis or conjugation; for Habrobracon, during metamorphosis. (4) Micronuclei divide by mitosis; for Habrobracon, in all tissues during cleavage, in the epidermis during moults, and in the nervous system and imaginal anlagen during metamorphosis. Macronuclei, if they divide, do so seemingly by amitosis. Multinucleate units are thereby produced in Habrobracon spinning glands. (5) Macronuclei of ciliates have been classified in type as physiologically active; those of Habrobracon are found in tissue differentiated to specialized function. — Therefore it appears that uniqueness in ciliate cytology lies not in dimorphism of nuclei, but in simultaneous presence of both types of nuclei within a unit which because of size has been termed a "cell".

HALL, B.M., Temple University, Philadelphia, Pa.: Genetic analysis of interspecific hybrids in the genus Bromus, section Ceratochloa. — Bromus catharticus Vahl, B. haenkeanus Presl., and B. stamineus Desv., all with 42 somatic chromosomes, were hybridized. The first generation hybrids had 42 somatic chromosomes and were low in seed fertility (between 5 and 15%) compared with the parental seed fertility of 95%. A diploid F_2 generation was grown from seed of the F_1 hybrids. A tetraploid F_2 was obtained from colchicine-treated F_1 hybrids. Both the 42 and 84 chromosome F_2 populations segregated for the morphological characters in which the parental species differed; they also segregated for seed fertility. A correlation was found between segregation for morphological differences and segregation for fertility. In diploid populations the correlation was positive, that is, the most extreme pheno-

types, those most different from phenotypic mean of their population, tended to be more fertile. In the tetraploid F_2 hybrids the correlations were negative. Selfing, and selecting for seed fertility to the F_4 generation was accompanied by a fairly rapid decline in fertility from 80% to about 30% in the tetraploid material. Under the same conditions the diploid lines regained the fertility of the original parents. The pattern of segregation in the F_3 and F_4 generations was the same as that already described for the F_2. It appeared that genetic instability, due to multivalent chromosome association, was the principal cause of decline in fertility of the tetraploid lines. (The author is indebted to Professor G.L. Stebbins, Jr., for making the original hybridizations.)

HANNAH, ALOHA, University of California, Berkeley, California.: Strapped, a digenic, sex-limited trait in Drosophila melanogaster. — Strapped, a mutant with the phenotype of scalloping of the wings, requires two factors for its expression. Stp-1 is located in the X chromosome at 50.6 ± 1, but is not an allele of scalloped (sd, 51.5). Stp-2 is in the right arm of chromosome-2, probably between c (75.5) and sp (107.0). The expression of Strapped is limited to the males. The females are never Strapped, even if they have a Y chromosome from the Strapped stock. Only about 15 percent of the Stp-1; Stp-2/+ males exhibit Strapped, and usually only of the lower grades, while most Stp-1; Stp-2/Stp-2 males are strapped although the scalloping may vary from a small nick in one wing to extreme vestigial-like wings. The expression of Strapped is modified by different environmental agents and various genetic backgrounds. In homozygotes, the expression of the phenotype is temperature sensitive; it shows greatest penetrance and expressivity at 26°C and is reduced at both 17° and 30°C. Modifiers in all chromosomes influence both penetrance and expressivity, and mutants, especially dominants (Cy, Pm, L, H, Sb), or independent factors in these strains have enhancing or inhibiting effects. Mutants with scalloped phenotypes (vg, fr) interact with Stp to increase the penetrance and expressivity of the scalloped phenotype in heterozygotes. Strapped is expressed in both female- and male-like intersexes, either homozygous for Stp-1 or without Stp-1 and having one or more Stp-2 chromosomes.

HERSKOWITZ, I.H. and W.J. BURDETTE, Louisiana State University School of Medicine, New Orleans, La.; Studies on a melanotic tumor in Drosophila melanogaster*.—A melanotic tumor phenotype, tu^{48j}, arose spontaneously in the Muller-5 stock in our laboratory, and a study was initiated to discover the genetic basis and influence of certain environmental factors on its appearance. Since preliminary experiments indicated the desirability of establishing a genetically uniform stock, a stock homozygous for chromosomes 1, 2, and 3, as well as stocks with various combinations of chromosomes from the tumor and a non-tumor stock were obtained. From a study of such crosses it

*This project was supported by a grant from the National Cancer Institute, U.S. Public Health Service.

was found that the incidence of the tumor phenotype is controlled primarily by a recessive or semidominant factor located in Chromosome 2. The tumor incidence was 39/283 when chromosome 2 from the tumor stock was homozygous and 1/266 when this chromosome was heterozygous in one experiment. The daily and the total tumor incidence was higher in females than in males from the same cultures. The data suggested a decreased incidence of tumors in crowded cultures. The percentage of flies bearing tumors decreased when supplementary live yeast was not added both to the stock medium and a smaller amount of stock medium for which brewers yeast was omitted. When a constant number of larvae was given diminished nutrition for different numbers of days, there was a decrease in incidence with an increased length of starvation. For example, 317 of 434 flies had tumors when given optimum nourishment, but only 145 of 417 had tumors when the available yeast was decreased for 6 days.

HIMES, M.H., Columbia University, New York, N.Y.: Studies on the chemical nature of "sticky chromosomes". – It has been stated by several cytologists, in particular Darlington, that stickiness of chromosomes is caused by depolymerization of desoxyribose nucleic acid (DNA). The author has sought evidence for the validity of this statement by using cytochemical methods for detecting differences between normal chromosomes and both genetically and experimentally induced sticky chromosomes. The material consisted of microsporocytes of Zea mays homozygous for the sticky gene and Allium cepa root tips treated with ethylene glycol and hot water. Two cytochemical tests for depolymerization of DNA were used. The first consisted of photometric determinations of the amounts of methyl green and Feulgen dyes combined with the chromosomes. It has previously been shown that the relative stainability by these two dyes depends on the degree of polymerization of DNA. No difference in methyl green - Feulgen ratios was found where differences in chromosome morphology occured, indicating no depolymerization of the type that characterizes degenerating nuclei. The second method involved a study of the relative rate of loss of DNA stainability following three different treatments - hot water, HCl and trichloracetic acid hydrolysis, and desoxyribonuclease digestion - which are known to cause depolymerization of DNA in vitro. The loss of methyl gree and Feulgen staining capacity after these treatments was the same in normal and sticky chromosomes. No evidence was found, therefore, to support Darlington's statement that stickiness of chromosomes is due to depolymerization of DNA.

HINTON, T. and J. ELLIS, Amherst College, Amherst, Mass.: A nucleic acid requirement in Drosophila correlated with a position effect.– A comparative study was made of the nutritional requirements of two strains of Drosophila melanogaster grown under aseptic conditions on a chemically defined medium. The two strains differ genetically in that one (Oregon-R) has the wild-type gene sequence while the other (Inver-

sion (2LR) 40d) has an inversion in the second chromosome with one break in heterochromatin resulting in a change in the appearance of the eye of the fly (a position effect). It was found that the wild-type strain does not require nucleic acid or any of its derivatives but that the strain with the inversion has a definite nucleic-acid-derivative requirement. The component of nucleic acid required was found to be adenine. Of 445 inversion-strain larvae raised on medium devoid of adenine, less than 5 per cent were able to survive beyond the larval stage and none became adults; of 503 wild-type larvae, 72 per cent pupated and 51 per cent became adults. Preliminary experiments, involving the replacement of the chromosomes of the inversion strain with various combinations of wild type chromosomes, indicate the adenine requirement to be a property of the chromosomal inversion. The degree of phenotypic expression of the inversion was found to vary inversely with the amount of nucleic acid in the medium. This suggests that the heterochromatic position effect is correlated with an iability to synthesize nucleic acid. (The work was done under a grant-in-aid from the American Cancer Society upon recommendation of the Committee on Growth of the National Research Council).

HORNER, T.W., R.E. COMSTOCK and H.F. ROBINSON, North Carolina State College, Raleigh, N.C.: The contribution of non-allelic gene interactions to variance in populations of selfed lines.— Estimates of additive genetic variance and variance due to dominance deviations have with a few exceptions been made ignoring variance resulting from the interaction of non-allelic genes. If such interactions are present they could cause considerable bias in estimates made with data from a population arising under self-fertilization. This study is concerned with the expected genetic variance between and within successive generations of selfed organisms in terms of the additive, dominance, and interaction components. The genetic model studied assumed a cross between two homozygous lines followed by successive generations of self-fertilization. An F_k sub-population within the F_n generation was defined as consisting of individuals descended from the same individual of the F_k generation. General formulae, concerning the F_n generation, are given for the variance between F_k sub-populations within F_{k-1} sub-populations, and for the variance within F_k sub-populations. A table of coefficients is presented to facilitate use of the variance formulas. Application of the formulae assuming several familiar types of gene interactions shows that in some cases rather large biases may result if interaction variance is ignored.

IBRAHIM, M.A.E., University of Minnesota, St. Paul, Minn.: Cytogenetic studies of tertiary trisomics in maize.— Tertiary trisomics of two types were identified in the progeny of maize plants heterozygous for T5-6a (breaks at approximately .12 of the long arm of 5 and .35 of the long arm of 6); or in later generations from the primary trisomic for chromosome 6 crossed with T5-6a. Both types showed a chain of

five chromosomes at diakinesis. In one type (6^5a) the extra chromosome is 6 with the translocated piece (.65) of its long arm replaced by the greater portion (.88) of the long arm of 5; while in the other type (5^6a) the extra chromosome is 5 with (.88) of its long arm replaced by (.65) of the long of 6. -- In tertiary (6^5a) there are three chromosomes attached to the nucleolus at meiosis, while in tertiary (5^6a) there are only two. The frequency of double nucleoli in the microspores was higher in the former: 7.03 as compared with .17 per cent for the latter. -- Tertiary (6^5a) showed trisomic ratios for pr and y, while (5^6a) showed only disomic ratios, indicating that pr is in the translocated piece of 5 and that y is not in the translocated piece of 6.

IVES, P.T., Amherst College, Amherst, Mass.: Mutator genes as a major cause of gene and chromosome changes in natural populations.- Previous reports have shown that a gene-like factor, high, contained in a second chromosome from a natural population of Drosophila melanogaster, increases the mutation rate ten times when homozygous. It increases the rate 2 to 7 times when heterozygous, depending upon other genes with which it is acting. It also causes inversions. Of 351 sex-linked mutations 17 were associated with inversions whose chromosome breaks, upon salivary analysis, appear to be distributed at random. The calculated minimum rate of inversions in all chromosomes is one per 400 germ cells in homozygous and one to four per 2000 in heterozygous tests. Mutation rates in 140 lines of flies recently isolated from a natural population were at least four times as high as in a long close-bred laboratory stock. This confirms earlier data (to be demonstrated) and agrees with the hypothesis that natural populations, being larger, contain a greater amount of genetic variability, including mutators, and should therefore show higher mutation rates than small population laboratory stocks. The thesis is advanced that the majority of gene mutations and chromosome rearragnements found in natural populations originate from the biochemical activity of mutators rather than from intramolecular thermal agitation, and that less active mutator alleles may be the cause of most spontaneous laboratory mutations.

KEHR, A.E., Louisiana State University, Baton Rouge, La.: A genetic explanation for tumor formation in Nicotiana hybrids.— A few genome combinations on Nicotiana characteristically produce spontaneous tumors which are initiated as far as can be determined within the plant itself as the result of its genetic constitution. These genetically controlled tumors develop apparently free from any known environmental stimuli such as bacteria, viruses, insects, chemicals, and similar tumefacient agents. Sixteen interspecific genome combinations, twelve of which were never previously reported, were found to produce tumorous growths. Tumor formation was expecially marked when one or more genomes of N. Langsdorffii were combined with certain genomes of other Nicotiana species, apparently as the result of a disturbance of the growth-regulatory mechanism, probably auxin metabolism. Species

always comprise harmonious systems in developmental processes which are integrated to produce normal growth. Certain genome combinations, and most likely particular genes, disrupt the normal physiological balance found in plants. Directly as a result of these unbalanced metabolic processes undifferentiated masses of secondary growths arise from various tissues of the plant, forming the tumorous condition.

KIMBALL, R.F., Oak Ridge National Laboratory, Oak Ridge, Tenn.: The relation between induced mutation and retardation of cell division brought about by ultraviolet irradiation of Paramecium aurelia. – Specimens of Paramecium aurelia which had been exposed to 2650 Å monochromatic ultraviolet were isolated; and the nonhereditary retardation of cell division was measured as time to the sixth division. After recovery from this effect, some of the descendants of each of the original irradiated animals were allowed to undergo autogamy to make them homozygous and so bring to light any genetic effects. The per cent of exautogamous clones of reduced vigor was taken as a measure of the latter. Time to the sixth division was found to be uncorrelated with per cent of reduced vigor within groups of animals exposed to the same dose. Both retardation of cell division and reduced vigor after autogamy are subject to photoreactivation; and so it is possible that both are due, at least in part, to some one primary effect of ultraviolet which is subject to photoreactivation. Even if such a common step does exist, variations in it cannot be the cause of the individual differences in the response of paramecia exposed to the same dose. These differences must be due to causes which act independantly upon the hereditary and nonhereditary components of the ultraviolet effect.

LANDMAN, O.E., Yale University, New Haven, Conn.: Formation of lactase in mutants and parental strains of Neurospora. – The enzyme lactase, catalyzing the hydrolytic cleavage of lactose, has been prepared in highly purified form from the parental strain Emerson 5256A of Neurospora crassa. With o-nitrophenol - β -galactoside serving as a substrate the following properties of this enzyme have been established: broad pH optimum centered at pH 5, temperature optimum between 50° and 62°C., Δ Ha 4,000 calories/mole, inhibition by galactose. Two successive steps in the formation of the enzyme on sucrose have been recognized. The Q_{10} for the rate of appearance of the finished enzyme is 2, while the Q_{10} of the preceeding step is very high. Strain Y-12016a is characterized by its poor growth on lactose. This strain grown on sucrose, however, contains a normal amount of lactase activity. The lactase of strain Y-12016a has been purified and was found to be identical with that of Emerson 5256A by all criteria tested. Strain Y12016a, however, differs from the parent strain in its response to lactose in terms of lactase formation. A concentration of.01% lactose in the medium increases lactase formation in the parental strain but depresses it 50% in Y-12016a. Four additional mutants besides Y-12016a, each characterized by poor growth on lactose, have been found to have rates of

lactase formation different from the rate of Emerson 5256A. Three of these mutants attain only 10-20% of the normal lactase activity. Two genetic classes affecting lactase formation have been definitely identified. Heterocaryon data suggest that as many as six loci may be involved.

LAUGHNAN, J.R., University of Illinois, Urbana, Ill.: Further studies on the mutation of A^b in maize. — The more extensive data now available on mutation of A^b in A^b/a individuals are in agreement with the interpretation that most A^d mutants, but not necessarily all, arise by crossing over between genes comprising A^b, with A^d representing a proximal component of A^b. This view is supported by independent evidence from A^b/Df plants in which there is a low rate of occurrence, if not an absence, of the A^d type. Six of the 56 A^d cases from A^b Et/a et plants were non-recombinants for et. These may be viewed either as point mutations or as double crossover events; the relative merits of these possibilities are discussed in the light of recent data. The frequency of occurrence of the A^d mutants in gametes of A^b/A^b plant is similar to that in sib A^b/a individuals. It is clear that in the former plants the origin of many of the A^d types is not explained by point mutation. On the present hypothesis they are interpreted as cases of unequal exchange.

LEVITAN, M., Virginia Polytechnic Institute, Blacksburg, Va.: Retention of a pericentric inversion in populations of Drosophila robusta. Individuals heterozygous for a pericentric inversion are expected to possess inferior fertility because crossing-over within the inversion would result in duplication-deficiency chromatids. This selective disadvantage has been used to explain the rarity of these inversions in nature, but forces the assumption of chiasmata localizations or more complex centric shifts to explain centromere position changes encountered in chromosomal evolution of various groups. Natural populations of Drosophila robusta contain a pericentric inversion, 2L-3, whose distribution is marked by geographic and altitudinal gradients. In experimental populations containing 2L-3 and the arrangement 2L directional changes in arrangement frequencies attributable to natural selection were observed at both high and low temperatures. In populations of 2L-3 and an overlapping inversion 2L-1 such changes occurred at the high but not at the low temperature. In some instances the frequency of 2L-3 decreased, but in other experiments it increased. In no case, however, was either arrangement eliminated from the population. Instead, equilibria were formed or indicated. This indicates that the adaptive superiority of the heterozygotes for these arrangements is responsible for the retention of this pericentric inversion in D. robusta populations.

LEWIS, H., University of California, Los Angeles, Calif.: The geographical distribution of supernumerary chromosomes in natural

populations of Clarkia elegans Dougl. — Clarkia elegans, a species ranging widely throughout the Sierra Nevada foothills and the Coast Ranges of California, characteristically shows nine pairs of chromosomes in the first meiotic division. However, throughout most of San Luis Obispo and Monterey counties supernumerary chromosomes are found in a large proportion of the individuals and the distribution of these plants has been mapped. Individuals with as many as six supernumeraries have been found although lower numbers are much more frequent. There are no obvious morphological differences which distinguish plants with supernumeraries from those with the normal compliment. It has not been possible to distinguish the supernumerary chromosomes from the basic set on the basis of behavior or staining but there are apparently at least two different chromosomes among the supernumeraries. Some individuals with two extra chromosomes show complete lack of pairing of the supernumeraries while in other individuals they are apparently homologous and pair normally. Many plants from populations in which supernumerary chromosomes occur show translocation configurations at meiosis of a ring or chain of four, two rings or chains of four or a ring of six. It is postulated that the supernumeraries have arisen from the unequal separation of the rings and it is possible that subsequent translocations may stabilize a karyotype with a higher chromosome number. This may be the mechanism by which some of the various chromosome numbers have arisen in Clarkia.

LIEB, MARGARET, Columbia University, New York, N.Y.: Ultraviolet-induced forward and reverse mutation in E. coli. — By the use of ultraviolet light it was possible to induce both the mutation of h+ to h- (histidine-requiring) and the reversion of h- to h+ in E. coli, strain 15. After the irradiation of washed h- suspensions, the frequency of h+ was not increased unless the cells were allowed to undergo about one division, that is, there were no zero-point mutants. No phenotypic expression of induced h+ mutants occured, even after 24 hours, if h- were placed in nutrient medium without histidine. The frequency of mutants increased slowly with dose; at 1% survival there was a ten-fold increase in mutant frequency. Induced mutation from h+ to h- was studied by means of modification of the penicillin selection technique of Davis, and Lederberg and Zinder. Zero-point h- mutants were recovered after ultraviolet treatment. The relative mutability of h- and h+ when irradiated is similar to their relative spontaneous mutability. Although recombination experiments have not been successful in this strain, there is some evidence to support the hypothesis that h- and h+ are dependent on changes in one gene. (Work supported by a fellowship from the National Cancer Institute, U.S. Public Health Service.)

LINDEGREN, C.C. and GERTRUDE LINDEGREN, Southern Illinois University, Carbondale, Ill.: Chromosome maps in Saccharomyces of genes controlling the fermentation of carbohydrates and the synthesis of vitamins, amino acids and nucleic acid components. — Selected inbred

stocks of Saccharomyces produce hybrids in which Mendelian segregation occurs with a high degree of regularity. An occasional tetrad undergoes an irregular segregation which is detected by tetrad analysis. Irregular segregations occurring in maize or Drosophila with the same frequency would be undetected. An effective method of screening yeast mutants for nutrilite deficiencies has yielded a group of fertile cultures which have been incorporated into the breeding stock. Four (or five) chromosomes of Saccharomyces have been mapped for genes controlling the fermentation of carbohydrates and the synthesis of various nutrilites: Chromosome I, HI (histidine), AN (anthranilic acid), PN (pantothenate), centromere, ADI (adenine), IN (inositol), PY (pyridoxine), and TH (thiamin). Total length 159 morgans. Chromosome II, centromere, G (galactose), AD2 (adenine), ME (melibiose). Total length, 93 morgans. Chromosome III, centromere, + (mating type). Total length, 22 morgans. Chromosome IV, centromere, PB (paraminobenzoic acid). Total length 22 morgans. Chromosome V, centromere, UR (uracil). Total length, 5 morgans. Chromosomes IV and V may or may not be different; UR and PB have not been used in the same hybrid.

LODEN, H.D., University of Georgia, Athens, Ga.: Genetic evidence of cryptic cytological differences in Gossypium hirsutum (L) and Gossypium barbadense (L). — The presence of cryptic structural differences between the species Gossypium hirsutum and Gossypium barbadense has been observed in genetic tests. The linkage between the loci R_1 (red plant color) and cl (cluster fruiting habit) was studied in both interspecific and intraspecific backcrosses. Results of the intraspecific backcross indicated approximately 16 percent crossing over, whereas, only approximately 8 percent of the crossover types were observed in the interspecific backcross population. Since previous investigations indicate complete homology for all chromosomes in crosses of Gossypium hirsutum x Gossypium barbadense, the absence of crossover individuals in the expected numbers in interspecific backcrosses has been attributed to cryptic cytological differences. In view of the fact that disturbance of linkage was observed for the loci tested (no other linkage group being available for testing in the species studied) it was concluded that cryptic differences exist between other chromosomes and that this mechanism has been important in the development of the species. (Data presented in this paper are part of a thesis submitted to the faculty of the Agricultural and Mechanical College of Texas in partial fulfilment of the requirement for the Ph.D. degree. Most of the data were collected while the author was Research Assistant, Department of Agronomy, Cotton Section, Texas Agricultural Experiment Station.)

LURIA, S.E., University of Illinois, Urbana, Ill.: Spontaneous mutations in the study of virus reproduction. — The frequency and distribution of mutants r and w in the yields of phage T2 from individual bacteria were analyzed. The distribution of mutants should be different,

depending on whether reproduction of the phage genetic material is logarithmic, with the newly produced elements acting as models for further replications in the same bacterium, or linear, with each new element being produced independently. The frequency of infected bacteria liberating mutants was about 2×10^{-2}. The distribution of mutants was clonal, each clone comprising between 1 and 20 mutants or more. The unimutational origin of each clone of mutants was tested by genetic crosses, proving allelism (probably identity) of mutants from one clone and nonallelism of mutants from different clones. The clone frequency diminishes with increasing clone size; the frequency distribution of clone sizes agrees well with the frequency anticipated by assuming logarithmic reduplication of the genetic determinants involved, with a constant probability of mutation per reduplication. The mutation rate calculated on this basis is between 1×10^{-4} and 5×10^{-4} mutations per reduplication. Since the mutant phenotypes r and w probably result from mutations at any one of over 100 loci, the mutation rate per reduplication is probably lower than 10^{-6}. These results are compared with data of other authors on the frequency distribution of recombinant phage particles in genetic crosses. Recombinants of each given type are apparently distributed at random (nonclonally) in individual bacteria, which suggests that recombination takes place in the host cell after the reproduction of the phage genetic material.

MAAS, W.K., U.S.P.H.S., Cornell University Medical College, New York, N.Y.: Studies on the mechanism of temperature-sensitive mutation. — Mutants which lose their nutritional requirements with shift of temperature have been described in Neurospora and E. coli. Mechanisms suggested but not proved have included a temperature-sensitive gene, a temperature-sensitive enzyme, and control of the reaction by different genes at each temperature. Another mechanism, production of an inhibitor at the higher temperature, is indicated by experiments on a mutant that requires pantothenate at 37° but not at 25°. Its ability to synthesize pantothenate from added precursors, β-alanine and pantoyl lactone, was tested in non-growing cell suspensions in glucose solution buffered at pH 7. Pantothenate was produced only at 25°, whereas wild type was equally active at both temperatures. However, mutant cells grown with pantothenate at 37° and tested at 25° immediately after harvesting are as active as cells grown at 25°, thereby excluding a temperature-sensitive gene and irreversible denaturation. Moreover, short exposure of cell suspensions to 37° in the presence of glucose at pH 5 causes further inactivation which persists on testing at 25°; this process does not occur with wild type. The inactivation is slowly reversible at 25° at pH 7 without growth. Dependence of inactivation on an energy source, as well as temperature, rules out reversible denaturation of an enzyme protein, and rather indicates inhibition resulting from metabolic activity; whether mutation causes increased production of an inhibitor or increased sensitivity of the enzyme is not apparent.

MACFARLANE, EILEEN W.E., Institutum Divi Thomae, Cincinnati, Ohio: Bioassay of growth-arresting substances penetrating Allium roots.- The organic mercurials PMOH and PMN produce gross effects in Allium roots similar to those of colchicine and auxines. Using PMOH in different solvents, the concentrations which produced the same grade of reaction, eventually after an hour's exposure and during 3 to 5 days treatment, were compared. When the latter was expressed as a percentage of the former, it provided an estimated assay of the poison penetrating the tissue in one hour. At 1 ppm this was from 18% to 20% in distilled water (DW), raw Ohio River water and Palm Beach tap water. The indicated penetration fell to a minimum of 7.5% to 12.5% between 2.5 ppm and 3.3 ppm and then rose sharply to 20% or 25% at lethal threshold. MLD for 1 hr. was about 4 ppm in Palm Beach water and DW and 5 ppm in River water. In these solvents an internal concentration of PMOH around 1 ppm (3.4×10^{-6}M) was fatal. In Cincinnati water 0.5 ppm internally was fatal and at 1 ppm in 1 hr. less than 10% penetrated. This seems to demonstrate the phenomena of reversibly reduced permeability of cells and the premortal rise in permeability. It provides a rapid method for comparing the internal concentrations for the same grade of reaction in (1) different aqueous media; (2) ionic imbalance plus enzymic poisons, growth hormones and narcotics; (3) efficacy of various substances in antagonism and synergism.

MARKERT, C.L. and R.D. OWEN, University of Michigan, Ann Arbor, Mich., and California Institute of Technology, Pasadena, Calif.: Immunogenetic studies of tyrosinase II. Strain and species comparisons.- Extracts prepared from several mutant strains of Glomerella possess negligible tyrosinase activity as compared to the very active extract from the standard type. The crude, water soluble extracts were made by grinding mycelia in a colloid mill, centrifuging, and lyophilizing the supernatants. Antiserum against the tyrosinase-containing standard type extract inhibited tyrosinase activity (see Owen and Markert, current abstract). When such an antiserum was absorbed by extracts prepared from tyrosinaseless mutants, then the supernatant remaining after absorption retained its tyrosinase-inhibiting capacity, although extensive antibody-antigen precipitation occurred during the absorption. Antisera against extracts from tyrosinaseless mutants produced a precipitate when added to an enzymatically active extract from the standard type; however, the tyrosinase of the extract was neither precipitated nor inactivated. Standard type Glomerella grown submerged in liquid culture produces very little tyrosinase compared to the great amount produced in surface cultrues on agar; extracts prepared from such submerged cultures of Glomerella neither absorb antibodies against tyrosinase nor stimulate the formation of antibodies against tyrosinase. Thus the absence of tyrosinase activity from an extract (mutant or standard type) is paralleled by an absence of the antigenic properties of tyrosinase. Neither the mutant strains of Glomerella nor the submerged

standard type cultures appear to synthesize significant quantities of proteins which are antigenically similar to tyrosinase. Antisera were also made against Neurospora and against purified tyrosinase from Psalliota. These antisera produced no interspecific enzyme cross-inactivation, although some cross-precipitation of non-tyrosinase material occurred.

MARTIN, A., JR.*, Mount Mercy College, Pittsburgh, Pa.: The effects of radioactive phosphorus on Cricetus auratus. — Males of the golden hamster, Cricetus auratus, have been given interperitoneal injections of various dosages of radioactive phosphorus and subsequently mated to untreated females. Histological and cytological examination of the tissues of the treated animals is in progress, and progeny are under observation. The maximum sub-lethal dose lies between six and inne microcuries per gram of body weight. A few animals survive a dosage of eight microcuries and recover from radiation sickness in about eleven days. Three microcuries induce permanent sterility in thirty days or less. Dosages of three or more microcuries result in the degeneration of Sertoli cells and the filling of the seminiferous tubules with fibrous connective tissue. One microcurie has no effect on sperms in the tubules in twenty-four hours, but in fifteen days the tubules are devoid of sperms. In thirty days, however, the testes again appear normal, and the tubules contain apparently normal sperms. Following dosages of one and three microcuries, the white blood cell count is much reduced. No statement is as yet available on effects on other tissues. The available progeny to date bear out the histological and cytological findings, in that none has been produced by males treated with three or more microcuries. When not completely destroyed, the germ plasm seems to be remarkably stable, in that progeny show no phenotypic abnormalities, litter size is unaffected, and offspring are of normal viability.

MC CLARY, C.F. and I.M. LERNER, University of California, Berkeley, Calif.: Extra-chromosomal effects in the transmission of egg-shell quality in chickens. — The thickness of egg-shells can be measured with considerable precision by determining the specific gravity of eggs. The hereditary nature of differences between birds with respect to this trait has been previously established by selection experiments. Partitioning of variance in two unrelated flocks of S.C.W. Leghorns has now revealed the fact that in addition to genetically determined differences in this character, which account for 15-30% of the total variation, there exist significant extrachromosomal maternal effects contributing approximately 10% to the total variance. Several independent statistical analyses of random-bred populations, experimental tests involving polyallel matings, and selection procedures confirm this finding. Although the physiological mechanism of transmission of the maternal effect is not known, certain consequences of the findings reported relating to breeding practice can be derived from the information at hand.

*Associated authors: C. Russ, M. Clements, I. Bocella and M. Calhoun.

McDONOUGH, E.S. and MARY ROWAN, Marquette University, Milwaukee, Wis.: A study of the effects of crystalline desoxyribonuclease on the salivary gland chromosomes of Drosophila Melanogaster. Desoxyribonuclease, free from proteolytic activity, crystallized and assayed by Dr. Michael Laskowski after the methods of Kunitz, was used in the study. The enzyme solution, containing 1 microgram of crystalline desoxyribonuclease per ml. in 0.2M. borate buffer pH7, was made 0.025M in respect to $MgSO_4$. Smeared chromosomes were incubated in this solution for varying lengths of time at 37°C. Chromosomes treated with buffer alone or with boiled enzyme-buffer were used as controls. Those digested for 1-15 minutes showed a gradual reduction in content of desoxyribonucleic acid as measured by the intensity of the Feulgen reaction, while controls gave a brilliant stain even after 2 hours treatment. Treatment for 15 minutes or longer resulted in Feulgen negative chromosomes. Examination with a phase-contrast microscope showed that the structural continuity was not destroyed and banded regions were still present in chromosomes exposed to the enzyme. Chromosomes treated for as long as 2 hours were similar in appearance to untreated ones; the bands seemed to be as numerous and at least as distinct. The granule-like structures, which appeared within the Feulgen-positive bands of control chromosomes, were discernible after digestion with desoxyribonuclease. These experiments add to the growing mass of evidence that desoxyribonucleic acid in itself is not an essential structural component of the chromosome and brings into question in this regard its relation to the gene.

McQUATE; J.T., Indiana University, Bloomington, Ind.: Chromosome loss occasioned by ultraviolet treatment of Drosophila spermatozoa. Adult males with a marked Y-chromosome, "$y^3.Y^1$", were treated with filtered ultraviolet light (ranging from 2537 to 3340Å from a Hanovia lamp, and mated to females containing achaete (ac^3). As $y^3.Y^1$ contains the normal allele of achaete, the ac^3 in the regular F_1 males was covered. Among a total of 19,309 F_1 males 23 achaete exceptions were obtained which were sterile, while there was only one sterile achaete exception among 8,046 control F_1 males. This difference has less than 2% probability of occurrence by chance. Such males represent the loss of the paternal X or of all or part of both arms of $y^3.Y^1$. This must have been caused either by breakage leading to acentric and dicentric chromosomes, or by lagging. However, breakage of the $y^3.Y^1$ chromosome with "healing", so as to form surviving chromosomes with a terminal deletion, thus lacking y^3, was not induced to an appreciable extent. This would have given fertile achaete exceptions, since Y^1 would have been present. There were only two of these among the F_1 males from treated fathers and one among the controls — approximately 0.01% in both cases. Hence breakage if induced is usually followed by union of broken ends. As an index of the treatment's genetic effectivness F_1 females were tested for X-chromosome lethals. Eighty-eight lethals were detected in 7,530 treated chromosomes (1.2%); in the control

material there was one lethal in 1,768 chromosomes (0.06%). (Work aided by grants from U.S. Public Health Service and National Advisory Cancer Council.)

MICKEY, G.H., Northwestern University, Evanston, Ill.: Studies on intersexuality in Drosophila. — Intersexes of Drosophila melanogaster for this study were derived from two sources, 1) triploid females and 2) an attached-X stock in which the attached-X chromosomes had broken apart. All those arising from triploid females exhibited rough eyes (facets enlarged) and rough wings, often with irregular margins, and were interpreted as triploid intersexes. The specimens derived from the attached-X stock probably were aneuploids with a diploid set of autosomes and one X chromosome and a fragment, and all were male type intersexes. The only sexual character with constant expression in all specimens was the male sex combs. All other external traits, both secondary sexual characters and genitalia, showed wide variability. Likewise the internal sexual organs ranged from almost completely male to almost wholly female. Generally a mixture of both male and female organs was present; often some parts were much reduced or rudimentary. Most often the gonads were small and intermediate or immature. Anal plates and genitalia were frequently rotated to various degrees. A mass of undifferentiated tissue, generally darkly pigmented and resembling a tumor-like growth, located between and below the genital plates was present in about half the specimens. A similar structure was described in D. virilis intersexes by Newby as a genital knob. (Work was begun while the writer was on a Guggenheim Memorial Foundation Fellowship and was supported in part by a grant from the Committee on Research Funds of the Graduate School of Northwestern University.)

MITTLER, S:, Illinois Institute of Technology, Chicago, Ill.: The genetic structure of wild populations of D. melanogaster. — Wild populations of Drosophila melanogaster were trapped during the summer and fall of 1947, 48, and 49, and analyzed for visible and second chromosome lethal mutations. The presence of the same mutations from year to year indicates that some D. melanogaster overwinter in the Chicago area. The most frequent visible gene found was Trident. As the weather becomes cooler in the fall the frequency of the Tri gene increases in the population. In early summer the Tri gene frequency is still high and decreases in mid-summer. Collections at various locations in the city indicate that the flies breed in small populations in early summer and that there is an overflow from one population to another at the end of August. There is a large daily variation in a collection at any given location. However, the monthly average, and even better the yearly one, give a clearer picture of the genetic structure and the gene drift in the populations.

NEWCOMBE, H.B., National Research Council, Chalk River, Ontario, Canada: Photoreversal of the mutagenic effect of ultraviolet light in E. coli. The mutagenic action of short (2537A) ultraviolet on Escherichia coli strain B/r can be partially reversed by post-treatment with long (3650A) ultraviolet. This reversal is most striking where the original dose is small (up to about 500 ergs per mm^2), about 95 percent of the potential mutants failing to appear. Where the dose is appreciably greater than this, two effects are noted: (1) the yield of mutants from short u.v. alone ceases to rise with increasing dose and in some cases actually declines, and (2) the mutagenic effect is more stable towards long u.v., only 20 to 30 percent of the potential mutants failing to appear after the post-treatment. The mutagenic effect of gamma irradiation is similar in its stability to that of high doses of short u.v. (Streptomycin-response variants, and colour variants on EMB-lactose and on mannitol-tetrazolium agar were used.)

O'MARA, J.G., Iowa State College, Ames, Iowa: The effects of chromosome substitution on competition between gametes. — Individuals of Triticum vulgare (n = 21) deficient for a pair of chromosomes and which had in place of the missing pair a pair of chromosomes from Secale cereale (n = 7) were crossed to T. vulgare. The resultant plants had 20 pairs of chromosomes and two univalent chromosomes, one univalent being the Triticum chromosome missing in the original plant and designated as chromosome IX by Sears (1944), the other being the Secale chromosome which had been substituted in its place. The male gametes produced by these individuals with two non-homologous univalent chromosomes will be of four types, if the products of misdivision are excluded -- nullisomic gametes, those in which either the Triticum or the Secale chromosome is present, and those in which both are present. If pollen from these plants is placed on the stigmas of normal Triticum plants, the resultant progeny should indicate the relative success of the different classes of gametes in competition. The data indicated that the normal gametes did not have an extreme advantage in competition. From 74 pollinations with the mixed pollen the data indicated that the substitution gametes effected fertilization once for each 2.3 normal gametes. The percentages of gamete successes in this experiment were 60% for normal gametes, 26% for substitution gametes, 8% for gametes with both chromosomes, and 6% for nullisomic gametes. Although the data are not adequate enough to be representative, they do seem to indicate that the substitution in gametes of a chromosome from a different genus may to a significant degree compensate for the loss of the normal chromosome in high polyploids like T. vulgare.

OWEN, R.D. and C.L. MARKERT, California Institute of Technology, Pasadena, Calif., and University of Michigan, Ann Arbor, Mich.: Immunogenetic studies of tyrosinase I. Effects of antisera on enzymatically active preparations. — Antisera were produced against lyophilized extracts of a standard type Glomerella cingulata. — When these antisera

were added to Glomerella extracts, the very high tyrosinase activity of such extracts was greatly diminished. Certain normal sera also interfere with this enzymatic activity, though to a lesser and slower extent; in contrast to the specific antibody of antiserum, such normal serum inactivators of tyrosinase are removed by dialysis. Antisera also precipitate the extract; at proper relative concentrations no enzymatic activity can be recovered in the supernatant liquid and little activity in the resuspended precipitate. The precipitating and inactivating materials in the antisera are recovered in the salt precipitated fraction containing the globulins, while normal serum globulins neither depress enzymatic activity nor precipitate it. Addition of substrate to enzyme at measured intervals after the addition of antiserum shows that the interaction between antibody and enzyme is rapid. A profound and immediate depression of enzymatic activity is noted when antiserum is added to an enzyme-substrate reaction system already in progress. These data and others to be presented suggest that the antibody inactivation is not a simple function of the aggregation of the precipitated enzyme, but it at least in part the result of a more direct interference with the active surface of the enzyme. This system therefore appears to be different from most enzyme-anti-enzyme systems on record and offers some promise as a tool for biochemical and immunogenetic studies (see Markert and Owen, current abstract).

PADDOCK, E.F., Ohio State University, Columbus, Ohio: A tentative assignment of the Fusarium-immunity locus to linkage group 5 in tomato.– Among 694 plants of a fusarium-inoculated F_2 from Missouri Accession 160 (II XX JJ YY UU HH TT WtWt) x Pennorange (ii xx jj yy uu hh tt wtwt), 119 (17.1%) died, presumably because they were ii. The chi-square probability of this deviation from a 25% expectation is less than 0.01. Among the 575 survivors, only 21 (3.6%) were jj, of linkage group 5. Recessive homozygotes of the 5 other markers of linkage groups 3, 7 and 10 were each present among the survivors in approximately the expected 25%. Bohn and Tucker (Mo. Agr. Exp. Sta. Res. Bul. 311, 1940) postulated the x locus in order to account for their average result, using a less severe inoculation method (Alexander and Tucker, Jour. Agr. Res. 70: 303-313, 1945), of approximately 10% ii in F_2. In the original postulation, x lowers the frequency with which pollen grains containing it accomplish fertilization, but only if they are competing against pollen grains containing X. Suppose x lowers this frequency to zero. Then any recessive linked to it in coupling phase could be recovered as a homozygote in F_2 only by crossing over. The phenotypically recessive individuals so recovered would represent only half the crossovers. The 3.6% recovery of jj is accordingly interpreted here as indicating 7.2% crossing over between j and x, and the 17% recovery of ii as 34% crossing over between i and x. Two loci linked with a common locus are linked with each other. Since j is in group 5, so also are i and x. Backcross tests are under way to determine whether the crossing over between i and j is 41.2% or 26.8%. Tests against

additional group-5 markers are also under way. The possibility that loci like x exist in other linkage groups is recognized. Among 649 plants of a fusarium-inoculated F_2 from Missouri Accession 160 x Baldwin's Brazilian (P.I. 148720),172 (26.5%) died. Apparently Baldwin's Brazilian is XX ii.

PAULEY, S.S., Maria Moors Cabot Foundation for Botanical Research, Harvard University, Petersham, Mass.: Flowering habits in Populus. In connection with the Cabot Foundation's studies of ecotypic variability within native Populus species, some general observations have accumulated on flowering habit. (1) In the aspens and balsam poplars the flowering period and time of seed maturity appears to be highly regular within the limits of ecotypic zones. Fluctuations in flowering time from year to year may, however, be considerable, the controlling factor apparently being current temperatures. The situation in the eastern cottonwood complex (P. deltoides), at least in the Mississippi Valley, is strikingly different. Here, within environmentally uniform local areas, seed fall during a single season may occur during May, June, July, and even early August. Such a seeding timetable for a species limited to bottomland sites, where destructive spring and early summer floods prevail, is obviously an adaptation of high survival value. (2) The age of first flowering in native Populus species shows considerable inter- and intra-specific variation. The cottonwoods and balsam poplars are in general somewhat laggard in reaching sexual maturity; but the aspens, especially P. tremuloides, may be extremely precocious: in New England, flower-bearing two- or three-year-old suckers in the wild state have been frequently observed. Aspen plants may also flower in the third year from seed. Out of several thousand individuals derived from intraspecific trembling aspen crosses made in the spring of 1948, a single plant produced several male flowers in the spring of 1950. This individual, significantly, was the only plant which developed lateral branches in the first season. This fact has suggested that if correlation exists between these characters, encouragement of lateral branch formation through the pinching-back of terminal shoots late in the first season may be an added technique for the stimulation of early flowering.

POULSON, D.F., Yale University, New Haven, Conn.: Physiological genetic studies on copper metabolism in the genus Drosophila. The mid gut epithelium of insects is able to accumulate mineral elements selectively. Certain cells of the middle mid gut of larvae (and adults) of Drosophila concentrate Cu more or less in proportion to its availability in the medium. The Cu uptake of these cells in larvae has been studied in numerous species and strains, and under differing conditions, with the aid of sodium diethyldithiocarbamate as a histochemical reagent and by fluorescence microscopy. This histo-chemically-detectable Cu is associated with a distinctive orange-red fluorescence which increases with Cu concentration in these cells. The fluorescence is measurable photographically and provides a means of quantitative comparison of Cu

accumulation by different species and strains. In the subgenus Sophophora differences have been established among members of the willistoni, melanogaster, and obscura groups; in the subgenus Drosophila among members of the funebris, repleta, and virilis groups. In D. melanogaster there are differences in several mutant strains. Present evidence indicates that this Cu accumulation is of the nature of a detoxication involving porphyrins and thus closely related to Cu tolerance. The mechanism is so effective that D. melanogaster and D. ananassae are able to reproduce readily on media containing 50 mg. $CuSO_4.5H_2O$/100 ml. equal to 160 μg. Cu/ml. Above this level toxic effects appear; at 320 μg. Cu/ml. flies rarely emerge. Standard laboratory media contain so little available Cu that none is ordinarily detectable in the middle mid gut cells of most species. Effects of constituents of the media were studied separately. Histochemical Cu is regularly detectable in the malpighian tubules, but does not appear to increase with the Cu concentration in the medium and the orange-red fluorescence is usually lacking there. Pathways of Cu absorption, transport, and excretion are being investigated with the aid of the radio-isotope, Cu-64. (Work aided by a Gosney Fellowship, Division of Biology, Calif. Inst. of Tech., Pasadena, March-Sept. 1949).

PREER, J.R., JR., and BERTINA M. BLAUCH, University of Pennsylvania, Philadelphia, Pa.: Inheritance of resistance to paramecin, the killer substance, in variety 2, Paramecium aurelia. – Approximately thirty different stocks of variety 2 have been tested for resistance to paramecins produced by six different killer strains (G, Gml, H, 36, 50, 308-2). Resistance is measured quantitatively by introducing ten animals into one-half milliliter of culture fluid containing paramecin and recording the number of animals after three days. The number found varies from zero to several hundred, depending upon the concentration and type of killer substance and the particular stock tested. In most cases each stock may be distinguished from the others by its characteristic pattern of resistance and sensitivity to the six killers. The effect of different kappas on resistance has been studied by determining the resistance pattern exhibited by the different killer strains and comparing it with that of the corresponding kappa-free strains. The genetic basis for difference in response exhibited by kappa-free stocks has also been studied. The difference between kappa-free stock 53 (more resistant to paramecin G) and kappa-free stock 30 (less resistant to paramecin G) appears to be due to multiple factors. Frequency histograms of the number of animals in tests on replicate cultures of these two stocks give two distinct curves. The F-1 is intermediate but somewhat more like 53. The F-2 by autogamy shows a much greater variance than the other distributions, varying from the extremes of each parent, and may be interpreted as showing at least a three-factor difference. Preliminary results indicate that further crosses designed to isolate single genes have apparently been successful.

RANDOLPH, L.F. and E. HERNANDEZ-XOLOCOTZI, Cornell University and U.S. Department of Agriculture, Ithaca, N.Y., and Department of Agriculture, Mexico, D.F., Mexico: Cytotaxonomic diversity of Tripsacum in Mexico. — From extensive explorations in Mexico and adjacent regions of Guatemala during 1945 to 1949 it is concluded that the present center of diversity of Tripsacum is in southwestern Mexico where Euchlaena and many types of primitive maize also occur. Cytotaxonomic field studies were made in central and northwestern Guatemala, the upland regions of southwestern Mexico from Acahuizatla northeastward to the environs of Mexico, D.F., the Fortin-Vera Cruz area of eastern Mexico and in western Mexico from Guadalajara northward to Tepic. The prevalence in these areas of tetraploid Tripsacum with multivalent chromosomal associations previously reported by others was confirmed, and in addition two new diploid species were discovered in Guerrero and described as T. maizar and T. zopilotense by Hernandez and Randolph. The former is more corn-like than any previously described Tripsacum and the latter is very grass-like in growth habit. Evidence that the present day tetraploids of Mexico and Guatemala are alloploids of these or closely related species was obtained from the successful crossing of T. maizar and T. zopilotense, the observed prevalence in geographically isolated areas of numerous populations of the tetraploid having distinctive combinations of the contrasting characters of the diploid species and the experimental proof of the cross fertility of the tetraploids. These observations are interpreted as strong support of the view that maize originated in Mexico.

RAUT, CAROLINE, Southern Illinois University, Carbondale, Ill.: A cytochrome deficient variant of Saccharomyces cerevisiae. — When plated on nutrient agar containing a sugar and tetrazolium, yeast strains capable of fermenting the sugar produce red colonies and those unable to ferment the sugar produce white colonies. Following ultraviolet irradiation of a haploid culture capable of fermenting sucrose a small percentage of white colonies was obtained on sucrose tetrazolium agar plates. Cultures from these white colonies, however, were capable of fermenting sucrose, as well as glucose. Spectroscopic examination of cultures from several white colonies showed absence of all cytochrome bands. The bands in the haploid parent are faint as compared with those of diploids baker's yeast, but the a, b, c, and d bands all appear to be present in the parent. When tested for fermentative capacity in the Warburg, the parent culture ferments glucose in air in the normal manner with an R.Q. of about 4. The variant ferments glucose with the production of CO_2 but absorbs no oxygen. In the single four-spored ascus obtained from a cross of the cytochrome deficient variant by a normal, two of the spore clones were white to very pale on tetrazolium agar, had no cytochrome bands, and did not absorb oxygen. The other two spore clones were deep pink or red on tetrazolium agar, had cytochrome bands, and absorbed oxygen. This is clearly mutation of a single gene involved in the production of the cytochromes. I wish to thank Mrs. Carl. C. Lindegren for the ascospore isolations.

RAVIN, A.W., Columbia University, New York, N.Y.: Genetic and non-genetic variability in citrate utilization by Aerobacter aerogenes. — Cultures of Aerobacter aerogenes grown in synthetic glucose medium under specific conditions are found to be heterogeneous with respect to the utilization of citrate as a sole carbon source for growth. When such cultures are plated in glucose and in citrate agar, a greater number of colonies appear in the former. Appropriate testing of colonies from the glucose agar and citrate agar plates proves that the differentiation of the original population into citrate-utilizing and non-utilizing components is not genetic, but is induced environmentally under the specific conditions that obtain in the stationary phase of a non-aerated culture, where the initial glucose concentration is not growth-limiting. By employing glucose cultures which do not exhibit this non-genetic heterogeneity in citrate-utilization, and by means of the penicillin technique for screening biochemically-deficient mutants, citrate-non-utilizing mutants of A. aerogenes have been obtained. Such mutants occur spontaneously wih with a frequency of about 10^{-5} in synthetic glucose medium. They are extremely stable, no reversions to the C+ condition having been detected. tected. — The C- mutant differs from the C+ parent not only in its inherited inability to utilize citrate, but also in its lower final level of growth in nutrient broth and in its inability to utilize succinate, fumarate, acetate, glutamate and aspartate. Both C+ and C- can utilize glucose, lactate and alanine. The finding that C- grows at the same rate and to the same final level as C+ in glucose provides further evidence that the tricarboxylic acid cycle does not operate in the aerobic breakdown of glucose in A. aerogenes. (Fellow, National Cancer Institute, United States Public Health Service, 1949-1950.)

ROTHFELS, K.H., University of Toronto and National Research Council, Chalk River, Ontario, Canada; Spontaneous and induced chromosome aberrations in the grasshopper Chloealtis conspersa. — The incidence of spontaneous chromosome aberrations in first meiotic metaphases of Chloealtis males is estimated to be .1 incomplete breaks, .01 complete breaks and .01 interchanges per cell. After an X-ray dose of 100 r the following classes of induced chromosome aberrations come successively into maximum: (1) incomplete breaks (24 hrs), (2) "stickiness" (5 days), (3) complete breaks (10 days), (4) interchanges (15 days), (5) incomplete nuclei (17 days). Over the range of 2- 300 r .05 incomplete breaks are obtained per nucleus per r. If the dose-effect curve remains linear at even lower doses, natural ionising radiations cannot account for more than 1% of the spontaneous abnormalities of this type. Similar conclusions were obtained with regard to the complete breaks and interchanges. These findings were tested directly by exposing grasshoppers at various distances from a Co^{60} source for 20 days. A dose rate of 500 x background was required to produce a clearly significant increase in chromosome aberrations over control animals.

RUBIN, B.A., Brookhaven National Laboratory, Upton, N.Y.: The

nature of streptomycin requirement and its effect on the genetics of streptomycin resistance in E. coli.* — The existence of several types of streptomycin-resistant mutants provides a tool for the study of dynamic aspects of bacterial populations. It was possible to separate multiplicative factors to show that occurrence of mutants so closely follows a Poisson distribution that a simple method for indicating that distribution is feasible. By this method it was possible to obtain, with predictable error, not only mutation rates but also the distribution of types. A stabilized frequency of mutants was reached in populations which could not be accounted for by growth rates alone. Much higher, but stable, levels and different distributions were attained after exposure to radiation. Apparent variations in mutation rates depending upon changes in medium and streptomycin level could be related to the various effects of these constituents on metabolism of sensitive, resistant and dependent organisms. Although the concentration of streptomycin in the medium was important, none of the genetic types detectably affected the concentration of the drug--either for growth inhibition (for sensitive cells) or growth stimulation (for requiring cells). Tests with different makes and types of streptomycin showed that no organic constituent in the fermentation liquor or trace impurity could replace streptomycin in the "requirement" phenomenon. Streptomycin salts which had different diffusion rates also had identical inhibiting and supporting properties. The inactivation of streptomycin by hydroxylamine HCl to less than 5% of its antibiotic activity failed to alter the growth-promoting property.

RUSSELL, ELIZABETH S., ELIZABETH L. FONDAL and LOIS JEAN SMITH, Roscoe B. Jackson Laboratory, Bar Harbor, Me.: A study of embryonic and postnatal erythrocyte levels in the normal and in anemic genotypes of the W-series. — The mean erythrocyte level was determined for the normal ww at the 14th and 16th days of embryonic life, and at 0 dyas, 14 days, and 28 days after birth, and for the four anemic genotypes (WW, WW^v, W^vW^v, and W^vw) at each stage where identified animals could be obtained. The most extreme genotype has been shown to be definitely anemic by the 14th day, and by the 16th day the anemia is well established in at least three genotypes. In each subsequent time interval, some increase in erythrocyte level was found in all genotypes. Since the absolute increase is always less in anemics than in normals, this is a hypoplastic type of anemia. However, all genotypes, normal and anemic, made approximately the same relative increase during each interval, thus indicating the same relative response to the physiological stimuli associated with the individual's growth. Certain genotypes tend to be lethal at particular stages. It is suggested that these deaths are due to a failure of blood formation to achieve the absolute level necessary for continued development at critical periods of rapid growth. These data suggest that the deleterious

*Research carried out at Brookhaven National Laboratory under the auspices of the Atomic Energy Commission.

genes of the W-series may cause a deficiency of a substance essential to erythropoiesis from earliest embryonic stages.

RUSSELL, LIANE B. and W.L. RUSSELL, Oak Ridge National Laboratory, Oak Ridge, Tenn.: Changes in the relative proportions of different axial skeletal types within inbred strains of mice brought about by X-irradiation at critical stages in embryonic development.— An extensive study on the effects of single doses of X-rays on (C57 x NB)F_1 hybrid mouse embryos, at stages ranging from days 1/2 to 13 1/2 after fertilization, revealed that the critical period for a posterior shift in the thoraco-lumbar border was from days 7 1/2 to 9 1/2, with day 8 1/2 exhibiting peak sensitivity. Two strains, one (129) showing considerable natural variability in number of presacral vertebrae and the other (B alb C) showing natural variability in this and in the thoraco-lumbar border, were chosen, as being probably more sensitive than the above uniform hybrids, for an extensive dosage comparison study. Almost 600 newborn mice irradiated during the critical period with doses of 25r, 50r, 100r, or 200r and 647 controls have been obtained. In the B alb C, an increase in fourteenth-rib development occurs with 25r on day 8 1/2, is greater with 50r, and complete with 100r or 200r. (Number of sternebrae and number of ribs articulating with the sternum are also increased but correlation with the thoraco-lumbar shift is incomplete.) Both B alb C's and 129's, whose normal presacral complement is 26-or-27 and 25-or-26 respectively, are shifted toward the higher number by irradiation on day 8 1/2 (50r and, possibly, even 25r) and, less markedly, on days 7 1/2 and 9 1/2. As had been anticipated, in strains where there is no natural variability, characters are considerably more resistant to radiation induced shift. This is true of the position of the thoraco-lumbar border in strain 129 and of the presacral number in the (C57 x NB)F_1 hybrid.

RUSSELL, W.L., Oak Ridge National Laboratory, Oak Ridge, Tenn.: The incidence of sterility and partial sterility in the descendants of X-irradiated mice. The data reported here were obtained incidentally in the course of another investigation. Adult male mice were given a single, whole-body, 80r/min, dose of 500r, 750r or 1000r, and then mated. Twenty-two male and 15 female offspring, all conceived within from two to 30 days after irradiation of the sire, were tested for fertility. Averaging the results over wide dose ranges is not justifiable, because of non-linearity of effect with dose, but is perhaps permissible, over the range used here, for a rough comparison with the results of other workers. Of the 37 animals tested, and whose sires received a mean dose of 669r, 8.1% were found to be completely sterile and 27.0% partially sterile. These percentages are in remarkably close agreement with the results of Snell and Hertwig for similar dose ranges. All of the ten partially sterile animals obtained in this experiment, and one other from another test, were found to transmit partial sterility to some of their descendants. Two of the 11 lines, however, do not fit the

simple interpretation of reciprocal translocation which Snell and others have established as the cause of the partial sterility in at least some cases. Both of these lines are producing some completely sterile descendants, one also yielding some almost sterile descendants. The data obtained so far are not adequate to settle whether a different type of change is involved or whether an additional translocation or other chromosomal or gene change has occurred.

SCHERR, G.H., University of Kentucky, Lexington, Ky.: The effect of 9:10-bishydroxymethyl-1:2-benzanthracene and alpha-naphthalene acetic acid on the cell division mechanism in Saccharomyces cerevisiae. — Both the carcinogen 9:10-bishydroxymethyl-1:2-benzanthracene (BB) and the synthetic auxin alpha-naphthalene acetic acid (ANAA) enhanced the yeast (Y) to filament (F) phase conversion in S. cerevisiae. The cells were exposed to suspensions of these chemicals while being cultured in a glucose-peptone-sodium chloride broth. Incubation was at 25° C with shaking. With a concentration of 0.0002 mg/ml of BB, F forms were detected after 10 hrs of incubation; similar results were obtained with ANAA. The cells comprising the filaments showed marked elongation, the length being approximately 5 times the diameter of the cell. The numbers of cells and of filaments of various lengths in cultures with and without ANAA were determined by the use of a haemacytometer. By interpreting these results together with those of determinations of the number of viable cells by plate counts, it has been determined that ANAA does not modify the rate of cell multiplication. These studies were not carried beyond 24 hours because longer incubation resulted in filaments composed of too many cells to permit accurate counting. One explanation that may account for the effects of the compounds studied is that dimorphism in yeasts may be governed by compounds similar to the auxins of higher plants, and that the effects of these and of the compounds studied is to interfere with the mechanism of cell multiplication and cell division. Further experiments are now in progress in order to resolve this concept. (The counsel of Prof. R.H. Weaver is acknowledged.)

SCHOTT, R.G., W.M. DAWSON, and A.C. COOK, U.S. Department of Agriculture, Washington, D.C., and M.L. KOHLI, The Civil Veterinary Department, Punjab, India: Inheritance of certain body measurements and measures of performance in steers. — Studies of inheritance of five body measurements and six measurements of performance have been made on 101 beef Shorthorn steers and 62 Milking Shorthorn steers raised and fed at the Agricultural Research Center, Beltsville, Maryland. The steers were weaned at 500 pounds and full fed to a slaughter weight of 900 pounds. Measurements and scores were taken in triplicate and averaged. Those on the live animals were taken just before slaughter. The 62 Milking Shorthorns had on the average significantly larger measurements than the 101 beef Shorthorns for height at withers, height at floor of chest, and length of body. They were significantly smaller

around the fore flank and in width of shoulder. They took 23 days less time to reach slaughter weight but were significantly lower in slaughter grade and carcass grade than the beef steers. Differences in average daily gain, efficiency, and dressing p›rcentage were not significant. Heritability of the different characters was estimated from the paternal half sib correlation, within years and breeds. Tentative estimates of the heritability percentages based on the combined group of 163 steers were: height at withers 100, height at floor of chest 83, final age 87, width of shoulder and length of body each 0, circumference of fore flank 58, average daily gain 59, carcass grade 52, dressing percentage 39, slaughter grade 38, and efficiency 38.

SHOWALTER, A.M., Madison College, Harrisonburg, Va.: The segregation of fruit shapes in selected inbred lines of Curcurbita moschata var. Golden Cushaw. — Beginning with a strain of the Golden Cushaw of excellent culinary qualities and high degree of uniformity of vine characteristics but of considerable variability of fruit shape, an attempt was made by selection and roguing to obtain uniformly large neck type of fruits. Little progress was made (thru five or six generations) until resort was made to controlled pollination. After three generations of hand pollination (selfing) of many selected lines, several distinct types are approaching constancy of breeding. Crosses of inbred lines of widely divergent fruit shapes produce first generation hybrids of intermediate shape. The presence of many genes affecting fruit shape in a quantitative manner is postulated.

SINGLETON, W.R., Brookhaven National Laboratory, Upton, N.Y.: Corn grass, a dominant monogenic spontaneous mutant, and its possible significance as an ancestral type of corn.* — Corn Grass, adominant gene affecting the gross morphology of the corn plant, arose as a spontaneous mutation. It gives good monogenic ratios in selfed and backcrossed progenies. Under field conditions, the plant tillers profusely making a clump of up to 100 tillers with very narrow leaves and no tassels. Such plants are scarcely recognizable as corn or closely related to corn. On these plants seeds are borne in very small "ears", producing usually from 0 - 20 seeds. An average of 116 such ears was 6.8 seeds. The clumps of plants may be divided, as many as sixteen plants having been produced by dividing one clump. This asexual reproduction and diffuse seed production are two characters that might make such a plant capable of growing and surviving in a wild state. Attempts have been made to induce reverse somatic mutations by x-raying, also by treating with P^{32}, and by growing under continuous gamma irradiation from Co^{60}. So far none has occurred. Tassels are not normally produced in the field, but in the greenhouse with reduced illumination in the short autumn days, Corn Grass plants produce few tillers, a more upright growth, and produce tassels with good pollen. Seeds of Corn Grass

*Research carried out at Brookhaven National Laboratory under the auspices of the Atomic Energy Commission.

are usually produced in podded ears although there is extreme variability in this regard among ears on the same plant. It seems possible the original ancestor of corn may have been a Corn Grass like plant and that corn arose as a single gene mutation.

SMITH, H.H., Cornell University, Ithaca, N.Y.: Fixing transgressive vigor in Nicotiana rustica. — A transgressive inbred selection of Nicotiana rustica, derived essentially from hybridization between two varieties, was obtained. Estimates of heritability were made from F_2 and first backcross data. Heritability of plant height was high (55%), and a substantial advance was made by selection. Heritability of leaf length was low (11%) and little advance was made by selection. In spite of the relatively low heritability of node number (12%), selection was effective in increasing the expression of this character. Comparison of F_1 and mid-parent values indicated that a preponderance of recessive gene effects for high node number differentiated the parental varieties and this may have augmented the effectiveness of selection. Non-allelic interactions were apparently not an important source of heritable variation, as indicated by scaling tests and evidence from double cross means. Reasons for expecting greater advances by selection and inbreeding, as contrasted to the use of first generation hybrids, in naturally selfed species were reviewed.

SMITH, L., LOUISE R. SIEBURTH and BARBARA NORBY, State College of Washington, Pullman, Wash.: The relation of oxygen concentration in barley seeds to the biological effects of X-ray. — In recent years a number of workers (cf. Hayden and Smith, Genetics 34: 26-43, 1949) have shown that the atmosphere (O_2, CO_2, N_2, vacuum) surrounding tissues has a profound effect on the biological effects of irradiation. Therefore an attempt was made to try to test the effect of increasing and decreasing the oxygen content inside germinating seeds prior to irradiation. This was accomplished by pre-soaking seeds for 24 hours in: 1) cooled, boiled distilled water (reduced supply of oxygen); 2) untreated distilled water (normal supply of oxygen); 3) distilled water to which oxygen was added (increased supply of oxygen). Preliminary observations indicate that no cell divisions have occurred at the end of the 24-hour period. At the end of pretreatments, the seeds were X-rayed (usually 1,500 r) under identical conditions in air. The seeds which were provided with additional oxygen were injured markedly more than those which had had a normal or reduced amount of oxygen. Seeds with the normal amount of oxygen were injured slightly more than those soaked in boiled water. Injury was measured in terms of survival and rate of growth (height) of seedlings. A summary of four experiments totaling 400 seeds for each treatment gave the following results. For the control, boiled (HOH, untreated HOH, and oxygen-added treatments, the survival values were respectively 1.9, 1.6, 1.3, and 1, and the heights were 3.4, 2.2, 2, and 1. Cytogenetic data are being obtained to supplement the observations on injury symptoms.

SMITH, S.G., Forest Insect Laboratory, Sault Ste. Marie, Ontario, Canada: Evolutionary changes in the sex chromosomes of Coleoptera. II. Flour beetles of the genus Tribolium. — T. castaneum has 9 pairs of autosomes, an X about the size of the smallest autosome, and a minute Y; these sex chromosomes are associated at metaphase I in a form resembling a parachute (subscript p). The species, therefore, conforms to the formula $9AA + Xy_p$ which is typical of beetles in general and tenebrionids in particular. T. confusum is a derivative species with 8 pairs of autosomes and a large XY sex pair (8AA + XY). The X is L-shaped, the Y rod-shaped and homologous to the longer arm of the X. These homologous elements are associated terminally at metaphase I and are presumable autosomal in origin. Despite this, at metaphase I the Y is negatively heteropycnotic. If, therefore, negative heteropycnosis denotes genetic inertness, the (m) is "monosomic" and the (i) disomic for the genes carried on this previously autosomal chromosome. All chromosomes show procentric positive heteropycnosis at pachytene. Then, the homologous regions of the X and Y are paired throughout their length and are presumably free to cross over; the original X segment is unpaired, fully heteropycnotic, and associated with the nucleolus. In T. confusum there are, therefore, within one nuclear division cycle, 3 types of chromatin: positive and negative heterochromatin, and euchromatin. It is shown that conventional pachytene pairing occurs between chromosome arms that, later, can be invariably differentiated as negatively heterochromatic and euchromatic. Crossing over might be expected to produce interesting complications, but they do not materialize. (m = male) (f = female)

SONNENBLICK, B.P., Newark College of Arts and Sciences, Rutgers University and Newark Beth Israel Hospital, Variable manifestation of skeletal anomalies in members of one family. — A history is presented in which skeletal malformations are expressed in seven individuals of three generations. Six individuals have been examined by us. The skeletal anomalies include syndactyly, congenital dislocation of the hip and "claw-hand" condition. Some affected individuals show only one trait and others more than one but in every instance the manifestiations differ from person to person. The concerned individuals range from a normal carrier (sister of the propositus), detectable when she transmitted the syndactylous trait, to a daughter of the propositus who recently died in infancy with multiple malformations including club hands, club feet of extreme degree, syndactylous fingers and toes, bilateral dislocation of the hips, marked asymmetry of the thorax due to underdevelopment of the left side, fixation of the knee joints and deformed tarsal bones. With her initial husband the propositus (who has several webbed toes and had a congenital dislocation of the right hip) had a normal child but the children of the second marriage show increasing severity of skeletal defects including the sublethal condition of the infant described. An attempt will be made to evaluate the variability evident in this pedigree.

SOOST, R.K., University of California Citrus Experiment Station, Riverside, Calif.: Cytology and genetics of five asynaptic mutants in Lycopersicon esculentum Mill. – Meiotic asynapsis in five unfruitful plants of the tomato variety San Marzano is conditioned by a single recessive gene in each plant. Test crosses indicate that the five mutants are non-allelic. It is proposed that the symbols as_1 to as_5 be assigned to them. Intensive cytological study of meiois in pollen-mother-cells was confined to two mutants -- as_1 and as_4. In both mutants chromosome pairing is variable at pachytene, diakinesis and metaphase, some cells displaying normal pairing in pachytene. Both mutants exhibit less pairing than the normal type, and mutant as_4, less than as_1. Chromosomal pairing in each mutant varies from day to day, from one temperature extreme to another, and from plant to plant. Chiasmata frequency measured at diakinesis varies in similar fashion. Again as_4 has a lower average number of chiasmata per bivalent than as_1 and both have lower means than the normal type. Univalents vary in their behavior at first anaphase; they may be distributed at random without dividing or they may divide equationally. At second division the previously divided univalents are distributed at random, whereas the others divide, the division often being delayed. This irregular distribution of chromosomes at both divisions results in the formation of micronuclei and aborted pollen. The percentage of aborted pollen varies from 70 to 100 percent. Genetic crossing over, as measured in the $WO\text{-}d_1$ region of Chromosome I is normal at least in the sporocytes that produce viable gametes.

SPARROW, A.H. and VIRGINIA POND, Brookhaven National Laboratory, Upton, N.Y.: Supernumerary chromosomes in diploid and triploid Trillium erectum L.* – About 800 plants of Trillium erectum L. were obtained from Hump Mountain, near Elk #Park, N.C. Two hundred thirty seven diploids were examined cytologically at first meiotic metaphase. One hundred ninety three (81.4%) were apparently normal diploids ($2n = 10$). The remainder had one or more very small supernumerary (or fragment) chromosomes as follows: 34 (14.4%) one, 7 (3.0%) with two, 2 (0.8%) with three, and one (0.4%) with four. These data deviate significantly from a poisson distribution, the value of P being 0.02. Irregular distribution of the fragment chromosomes occurs during meiosis, followed by some loss due to lagging. Hence their number in microspore nuclei is highly variable. In addition to the diploids examined, three triploid plants were found, of which two had two extra chromosomes and one had three. Of the 240 plants examined 47 (19%) had one or more supernumerary chromosomes. The high percentage of such plants would indicate that they may have a positive selective value, or at least that the extra chromosomes have no serious deleterious effect. Since these chromosomes are small they may sometimes be confused with radiation induced fragments. This hazard can be avoided in radiation experiments by proper screening of the material before or during the experiment.

*Research carried out at Brookhaven National Laboratory under the auspices of the Atomic Energy Commission.

STEINITZ-SEARS, LOTTI M.S., University of Missouri, Columbia, Mo.: Cytochemical demonstration of the location of some protein-bound amino acids. - By means of three cytochemical reactions the location of protein-bound arginine, histidine-tyrosine and tyrosine-tryptophane has been studied during mitosis and interphase. The location of these amino acids in chromosomes, spindle, nucleoli, heterochromatin and cytoplasm will be demonstrated by means of photomicrographs and in preparation under the microscope. The techniques used are a new modification of Thomas' Sakaguchi reaction, and adaptations to cytological material of the Pauly diazo reaction and of Pollister's Millon reaction.

STRONG, L.C., Yale University, New Haven, Conn.: Loss of correlation between pink eye gene and susceptibility to fibrosarcoma in mice. — Mice of inbred strains with pink-eyes (I, JK) show a reduced incidence of chemically induced fibrosarcomas below the rate shown by mice with dark eyes. The F_2 generation of a cross between dark eyed and pink eyed mice (Brs x I) produced evidence that the pink eyed segregates show approximately 15 percent fewer tumors at 325 days of latent period, indicating a correlation between pink eye and a reduced fibrosarcoma susceptibility. Pink eye has appeared in a dark eye descent (Br subline of NHO) following the subcutaneous injection of methylcholanthrene. The pink eye mutant has been continued for twelve generations by mating a pink eye individual to a heterozygous dark eye mouse. This descent has produced 641 mice or 323 dark eye: 318 pink eye. There is in this mutant descent no difference in susceptibility to fibrosarcoma between dark eye and pink eye mice (latent period dark eye 202.8 days = pink eye 219.8 days). These facts are interpreted by a loss of correlation between the pink eye gene and susceptibility to fibrosarcomas. Thus a mutation at the dark eye gene to pink eye has occurred without a concomitant change in an associated locus which influences fibrosarcoma susceptibility.

SWANSON, C.P. and S.H. GOODGAL, Johns Hopkins University, Baltimore, Md.: The effect of metabolic inhibitors on the ultraviolet-induced mutation rate in Aspergillus terreus. — If short ultraviolet radiation induces mutations by an indirect process rather than through direct absorption by the reacting genic molecules, as a number of published results suggest, it may be possible to modify the frequency of mutations produced by a given UV dose through pre- or post-treatment with a specific agent which inhibits or accelerates the mutation process. If a modification of the mutation frequency is achieved, the information gained regarding the nature of the process will depend upon knowledge of the specificity of action of the agent employed. With this in mind, several metabolic inhibitors have been tested as possible modifying agents, with the spores of Aspergillus terreus serving as test cells. The agents were used in the form of a pretreatment for 30 minutes at a concentration of 0.001 M in an unbuffered aqueous solution, and the frequency of

morphological mutations served as the criterion of effect. --- KCN was found to be without effect either as a mutagenic agent when used alone, or as a modifying agent when used in combination with UV. DNP, on the other hand, induced a considerable rise in the UV induced mutation rate, particularly at the lower doses of UV, although it was without effect when used alone. The rise in mutation frequency with DNP pretreatment occurred without any appreciable effect on the frequency of survival, indicating that the DNP was effective in modifying the mutation process while exerting no selective action on survival. Preliminary experiments indicate that posttreatments with DNP, and with non-mutagenic concentrations of N-mustard, are also effective in materially increasing the UV induced mutation rate, thus providing support for the hypothesis that UV induces mutation through an indirect rather than a direct process.

TASCHDJIAN, E., Loyola University, Chicago, Ill.: The evolution of the Mendelian concept of "anlage". — A comparison is made between the meaning ascribed to the term "anlage" in Mendel's original publication and the translation made of this term by Bateson. It is shown that whilst the original meaning is that of "disposition" or "design", Bateson translated this term wrongly as "material". It is thought that much of the sudden popularity of Mendel after his previous neglect was due to this wrong translation. The early geneticists conceived the gene as an inert particle and the genotype as a mere agglomeration of such particles which were supposed to multiply by division and to be transferred from ancestor to offspring. The discovery of the position effect, of interchromosomal linkage and of interchromosomal crossing-over suppressors has shown that the genotype is not a mere agglomeration, but a formed entity. Such a formed entity cannot be inherited by division and transfer but rather by a copying process during which a new gene is built up out of assimilated material by the action of the parental gene. Demerec's studies of labile genes in Delphinium have shown that such a process actually occurs in nature and thus one has come more and more to conceive the "anlage" as a template, a concept which is much more akin to Mendel's original concept of the gene than to Bateson's interpretation.

TEAS, H.J. and E.G. ANDERSON, California Institute of Technology, Pasadena, Calif.: Blue fluorescent, a new mutant in maize.— Ultraviolet light examination of an extensive series of Bikini progeny corn seedlings revealed a family segregating for bright blue fluorescence (recessive) in place of the usual dull red color; the mutant seedlings in this family were indistinguishable from the normals by daylight. As the mutant plants grow, the blue fluorescence decreases, becoming undetectable in the leaves of half-grown or mature plants. Anthers of both heterozygous and homozygous plants are blue fluorescent. Chromatographic adsorption columns run on acetone extracts of blue fluorescent seedlings show that chlorophyll is present in approximately normal

amount, but that the mutant seedlings fail to show the characteristic red chlorophyll fluorescence because of the masking effect of the blue fluorescent material. Paper strip chromatograms run with butanol-water reveal three major blue fluorescent bands in mutant seedlings and anthers that are absent or extremely faint in normals. Eluates from each of the major bands are active as tryptophane substitutes for Lactobacillus arabinosus but not Streptococcus faecalis (the former is known to utilize indole or anthranilic acid in place of tryptophane, but the latter requires tryptophane). Crystalline material isolated from one of the blue fluorescing bands has been identified as anthranilic acid by absorption spectrum, pH-fluorescence curves and mixed melting point determination.

VICARI, EMELIA M., Jackson Memorial Laboratory, Bar Harbor, Me.: Genetic factors and adrenal cortical carcinoma with relation to sound-induced convulsions. — The first responses to audio-stimulation of one thousand genetically homogeneous mice of strain dilute brown showed 80 to 90% individuals susceptible to convulsive seizures between the ages 25 to 50 days. Fatal seizures occurred in 40 to 50% individuals. Between 50 to 70 days, 30% individuals were susceptible; over 70 days none were. But a group of 500 mice of another strain, the extreme dilution, also genetically homogeneous, likewise tested, showed different reactions. Here the age susceptibility started from adolescence through adult life into old age. After three months the seizures increased in severity with advancing age. Under 70 days the seizures occurred in about 55% individuals with complete recovery. At ages 80 to 200 days the incidence was 85% and the post-convulsive pattern showed a rigid posture like catalepsis, lasting several minutes followed by temporary paralysis. From 200 to 250 days the incidence was 90%, and over 250 days 100%. Seizures were usually fatal in the old age level, 15 to 23 months. The extreme dilution strain is chiefly characterized by its spontaneous adrenal cortical tumors, which develop into carcinomas along 14 to 25 months. The dilute brown strain is not so characterized. The close association of the convulsive seizures dwith adrenal cortical carcinomas points to the adrenal cortical hormone as the important factor in the gene action for the expression of seizures.

WAGNER, R.P. and C.H. HADDOX, University of Texas, Austin, Texas: The in-vivo synthesis of pantothenic acid by "pantothenicless" Neurospora. — The pantothenicless mutants, 5531 and 34556 which had previously been shown to be capable of synthesizing pantothenic acid from the presumed natural precursors, β-alanine and pantoyl lactone only under in vitro conditions, have been found capable of synthesizing this vitamin in vivo as well, provided the culture is vigorously aerated, and pantothenic acid is present initially to start growth. Synthesis of pantothenate under these conditions by the mutant in the absence of precursors proceeds more rapidly than in the case of the wild type. When precursors are present, both mutant and wild type synthesize pantothenate

at approximately the same rate. Mutant mycelium grown under conditions of aeration is capable of synthesizing pantothenate from the precursors in resting cell preparations, but is unable to continue growth in minimal medium in the absence of pantothenic acid. Mutant mycelium grown in the presence of the precursors is no more active in resting cell preparation than that grown in their absence. The evidence continues to support the view that the pantothenicless mutants possess the enzyme system necessary to carry out the synthesis of pantothenate from these precursors, but are prevented from doing so by some as yet unknown mechanism.

WALLACE, B., Long Island Biological Laboratory, Cold Spring Harbor, N.Y.: Mutations induced by chronic radiation. — Males and females of the ore-R strain of D. melanogaster have been subjected to chronic irradiation in a number of experiments. 1. Chronic x-ray treatment of approximately 108r per day (7 minutes per treatment) for 5, 10, 15, 20, and 25 days after deposition of eggs gave, in males, 1.21 ± .22%, 3.99 ± .59%, 4.60 ± .42%, 6.14 ± .66%, and 5.20 ± 1.23% sex linked lethals. The control rate was .19 ± .10%. The proportion of recoverable lethals increases linearly with dose for 20 days; there is no increase after that time. 2. Males and females carrying lethal-free second chromosomes were exposed continuously to gamma-rays for 18 days (approx. 2200r) at 25° while they developed from eggs to adults. 3772 second chromosomes from these treated males were tested for lethals; 456 (12.1± .5%) were recovered. No attempt was made to test for clusters. 1187 second chromosomes from treated females were also treated; 69 (5.8 ± .7%) lethals were obtained. The difference between the frequencies of recoverable lethals in the two sexes is significant. Preliminary tests for translocations coincident with these lethals indicate that they occur with a low frequency; no translocations were coincident with the 69 lethals derived from females, 3 were present among 99 independent, "randomly" chosen lethals from treated males. A test for allelism made with 100 lethals of independent origin (obtained from different males) gave 14 cases of allelism in 4950 tests. A minimum of 400 (234 - 718) loci on the second chromosome are capable of mutating to lethality under these conditions. (Work done under AEC contract #AT(30-1)-557.)

WALSH, M.P., Boston College, Chestnut Hill, Mass.: The effect of aminopterin on mitosis in Allium cepa. — Aminopterin is one of the folic acid analogues synthesized by Lederle Laboratories and shown by some clinical investigators to have a definite inhibitory effect on the development of neoplastic growth. A need was felt to observe and correlate the events taking place within the actual cells subjected to the drug. Onion root tips were grown in concentrations of the drug ranging from 0.1% to 0.005% for 1-20 hours. Controls and treated root tips were fixed in Carnoy, smeared and stained with aceto-o-cein. All root tips exposed to a 0.001% solution for 1-1 1/2 hours showed all the usual C-mitotic

effects. A cessation of longitudinal growth and a slight increase in girth of the meristem were also observed. Diplochromosomes, definite contraction of the metaphase chromosomes, polyploidy, spindle inhibition, binucleate and multinucleate cells were found in all treated specimens. With longer exposures mitotic activity steadily decreased and at 18 hours complete inhibition of mitosis appeared. With higher concentrations C-mitotic effects were rarely seen and mitotic activity ceased at 3-10 hours. The clinical results of aminopterin are very likely due to a reversion and cessation of mitosis as indicated in the present investigation. It is possible that enzyme disruption may play an important part in producing some of these cytological phenomena.

WHITING, P.W., University of Pennsylvania, Philadelphia, Pa.: Linkage in Mormoniella. — The dark red eye color tomato, to, is low in viability and fecundity. Many unmated to females (f) produced only 32 to males (m). Thirty to f by + m produced only 112 + f and 24 to m. +/to f produced + m. 1012, to m. 446. +/to f. by to m. produced f. + 49, to 6. Garnet tomato, ga to, eye color is "orange". ga/ga to f. produced m. ga 412, "orange" ga to 85. Progeny from +/ga to f. were m. + 366, "red" 516, "orange" 190. The two "reds", ga and to, are not conveniently separable. Oyster white, oy, masks ga and to. ga oy/ga to (garnet) f. produced m. ga 159, ga to "orange" 113, oy 279. ga oy/to (wild type) f. produced m. + 75, ga and to "red" 120, ga to "orange" 51, oy 229. Evidently the three loci segregate independently. Purple body color, pu, is linked with oy. +/oy pu f. produced m. +824, oy 73, pu 63, oy pu 801. oy shows complementary allelism with vermilion, vm, and with scarlet, st, the compound f, oy/vm and oy/st, being wild type (brown-eyed). oy/vm pu (wild type) f. produced m. oy 2724, oy pu 313, vm 301, vm pu 2508. oy/vm pu f. by vm pu m. produced f. + 685, pu 75, vm 61, vm pu 515. st/oy pu (wild type) f. produced m. st 835, oy 105, st pu 97, oy pu 720. oy ga/pu (wild type) f. produced m. + 53, ga 60, oy 659, pu 301, ga pu 306, oy pu 92. Crossovers between pu and the oy series total 1,293 among 12,171 or 10.62 percent.

WHITTINGHILL, M., University of North Carolina, Chapel Hill, N.C.: Evidences from complementary crossover classes as to the time of crossing over. — By using a method of Fisher studies have been made to see whether the complementary crossover classes of entire experiments vary more readily than one would expect for products of meiotic crossing over. Excessive variation is a possible although not a necessary result of oogonial crossing over, whereas variation should be no greater than that given by the binomial expansion if crossing over occurs only at meiosis. In a nitrogen mustard experiment with Drosophila melanogaster where recombination values were quadrupled, complementary crossovers for the region st-cu were extremely variable. In a gamma ray experiment showing a two and one-half fold increase double crossovers in the right arm of the third chromosome of rucuca heterozygotes showed a wide spread both

ways from the mean expectation of complementary classes. Data from other types of experiments using X-rays, heat, or natural aging, previously published or new, show slight indications of this inequality often enough, it is believed, to indicate that the variability long known in Drosophila linkage experiments may be of gonial origin.

YOST, H.T., JR., Johns Hopkins University, Baltimore, Md.: An analysis of combined infra-red and X-ray effects on Tradescantia chromosomes. — X-rayed Tradescantia microspores have been given pre- and post-treatments with infra-red radiations. In all cases, percentage increases of 50--120% in chromosomal aberrations were observed in the infra-red-treated cells. Post-treatments have been given as late as 96 hours after X-radiation with no apparent decrease in the effectiveness of the infra-red radiations. From these data the conclusion may be drawn that the determination of the type of aberration recovered (chromosome or chromatid) is independent of the time of recombination, and dependent solely upon the singleness or doubleness of the chromosomes at the time of X-radiation. Studies on Tradescantia chromatid aberrations indicate that the infra-red-induced increases show a non-linear relationship to the dosage of infra-red given. These studies and other concerned chiefly with X-ray dosage relationships and spectral dependency permit some conclusions concerning the mechanism by which infra-red radiations produce their effect.

ZALOKAR, M., University of Washington, Seattle, Wash.: Production of p-amino benzoic acid in Neurospora and adaptation to sulfonamides.— Neurospora can be made resistant to sulfonamides (SA) by adaptation, not transmissible through the sexual cycle, or by mutation, as shown by Emerson and Cushing. It has been suggested that adaptation of microorganisms to sulfonamides may consist of an increased production of p-aminobenzoic acid (PABA). We have measured, by chemical and bioassay methods, the amount of PABA produced by different strains of Neurospora. The concentration of PABA found in the culture liquid is assumed to be proportional to the production rate. The wild strain and the sulfonamide requiring strain produce approximately 10^{-7} molar solution of PABA in 7 days. The strain carrying the gene for sulfonamide resistance shows a slightly higher production of PABA. The wild strain, adapted to SA by gradual transfers to higher SA concentrations, shows about five times as high a concentration of PABA in the culture liquid. The capacity to produce more PABA is retained during at least two subsequent transfers in the absence of SA. Crossing experiments are in progress to show the genetical or adaptive nature of this change. Under special growth conditions in aerated flasks, the Neurospora mycelium releases anthranilic acid in the medium. Anthranilic acid production is increased five fold in strains adapted to SA. The p-amino-benzoic acid-less strain does not release any anthranilic acid under similar conditions. This suggests a common precursor for both arylamines.

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A PERIODICAL RECORD OF INVESTIGATIONS BEARING ON HEREDITY AND VARIATION

Founded in 1916

by

GEORGE H. SHULL

with the cooperation of

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CORRIGENDA

Volume 34, 1949

Page 475, *line 4*, "In his experiments" should read "In one experiment"; *line 7* for "but it was also etc." should read "It was a cross in which neither parent carried an inversion, hence this combination had an effectively short interstitial segment (due to reduced crossing over brought about by the translocations) and was accompanied by the expected higher frequency of adjacent 2."

Page 653, table 2, for "S-12 (Anti-isogenic)"
read "S-13 (Anti-isogenic)"

Page 670, line 8 from below, for "$=2^{\alpha}$"
read "$=2^{s}$"

Page 678, lines 14 and 15 from below, for "$\bar{v}^{(1)}$" and "$\bar{p}^{(1)}$"
read "$\bar{v}^{(0)}$" and "$\bar{p}^{(0)}$"

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